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Project Risk Assessment and Corporate Behavior

Creating Knowledge for Sustainable Business

Edited by

António Abreu

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Editor

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About the Editor

António Abreu

António Abreu is currently professor of Industrial Engineering in the Polytechnic Institute of Lisbon (ISEL), where he now holds the position of associate professor with habilitation.

Before joining the academic world in 1998, he had an industrial career since 1992 in manufacturing industries with management positions.

He is member of several international associations, e.g., IFAC at TC5.3 Enterprise Integration & Networking, ISO/TC 258, and INSTICC –Institute for Systems and Technologies of Information, Control and Communication. He is co-founder of SOCOLNET - Society of Collaborative Networks.

As researcher, he has been involved in several National and European research projects.

He has been involved in the organization and member of the program committees of several national and international conferences, as well as member of review board and editorial board of several international journals.

He has more than 150 publications in books, journals, and conferences proceedings in the area of logistics, project management, quality management, open-Innovation, risk management, and lean management.

Preface to "Project Risk Assessment and Corporate Behavior: Creating Knowledge for Sustainable Business"

The business world has changed dramatically during the last years, and further changes are expected to keep on coming.

In a VUCA world (volatile, uncertain, complex, and ambiguous), organizations to achieve a sustainable competitive advantage must learn to mitigate risk and prioritize performance and innovation.

In the last decade, as a way to respond to market demands, projects emerge as a way for organizations to implement their strategic objectives in order to respond to a need, opportunity, or threat in an efficient way.

Moreover, organizations alone, do not always hold the necessary resources to enhance performance, and, therefore, organizations often engage in collaborative projects, where they interact with business partners, customers, universities, scientific institutes, and public institutions, where, through the exchange of ideas, resources, and technologies, facilitate the achievement of individual and collective goals. Indeed, some authors and researchers, argue that, among many other factors, the ability of an organization to develop projects is the actual major factor for whether the organization reaches success.

It must be stated that not all organizations have production, but all organizations have projects. The risk is the probability of occurrence of a specified uncertain event and its consequence. Any factor that affects the performance of a project can be a source of risk for organization.

The risk arises when this effect has an uncertain and significant impact on organization competitiveness. In this context, the management of risk in projects and its impact in corporate is currently one of the main topics of interest for researchers and practitioners working in the area of project management.

This e-book comprises the edition of the Special Issue entitled Project Risk Assessment and Corporate Behavior: Creating knowledge for sustainable business, published by *Sustainability*, and includes a collection of 11 papers that discusses theoretical approaches and case studies, focused on a combined effect between Project Risk Assessment and corporate behavior in order to support the sustainability and business resilience in a competitive environment.

The e-book will be of particular interest to entrepreneurs, researchers, and policymakers.

And the last but not least, as guest editor of this e-book, I would like to express my profound gratitude for the opportunity to publish with MDPI. This acknowledgment extends to the *Sustainability* Editorial Office, and especially to Hayley Chen, who has supported me constantly throughout this process.

It was a great pleasure to work in such conditions. I look forward to collaborating with *Sustainability* in the future.

António Abreu
Editor

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Article

A Model to Manage Cooperative Project Risks to Create Knowledge and Drive Sustainable Business

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Abstract: Efficient cooperation between organizations across all the phases of a project lifecycle is a critical factor to increase the chances of project success and drive sustainable business. However, and according to research, despite the large benefits that efficient organizational cooperation provides to organizations, they are still often reluctant to engage in cooperative partnerships. The reviewed literature argues that the major reason for such a trend is due to the lack of efficient and actionable supportive models to manage organizational cooperative risks. In this work we propose a model to efficiently support the management of organizational cooperative risks in project environments. The model, MCPx (management of cooperative projects), was developed based on four critical scientific pillars, (1) project risk management, (2) cooperative networks, (3) social network analysis, and (4) business intelligence architecture, and will analyze in a quantitative way how project cooperative behaviors evolve across a bounded time period, and to which extent they can turn into a cooperative project risk (essentially potential threats). For this matter, the MCPx model will quantitatively analyze five key project cooperative behavioral dimensions, (1) communication, (2) information sharing, (3) trust, (4) problem solving and (5) decision making, which show how dynamic interactions between project stakeholders evolve across time. The implementation and functioning principles of the MCPx model are illustrated with a case study.

Keywords: project management; risk management; social network analysis; cooperative networks; business intelligence; project cooperative risks; knowledge creation; sustainable business

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1. Introduction

In today's complex, turbulent, and unpredictable business landscape, if organizations want to achieve success, meet market needs and demands, or even just survive, they must develop strategies that boost performance and innovation [1,2]. The literature argues that both innovation and performance strongly depend on how an organization's C suit manages and motivates their employees to overcome daily challenges, such as different cultures, different time zones, different geographic locations, or different functions, while simultaneously nurturing the capacity and will to continuously learn and adapt [1,3]. The literature also shows that the adoption of an ambidextrous leadership style (characterized by the exploitation of present conditions to optimize current business model operations, while simultaneously exploring new opportunities that contribute to redefining business models by taking decisions in a pioneering, risky way) increases the chances of achieving sustainable competitive advantages [4,5]. In addition, the literature shows that the ability to work in cooperative networks in both organizational and individual levels is a critical factor for an organization to achieve success and generate actionable and unique knowledge [2,6–8]. In fact, the latest research in organizational theory and management

argues that although individual knowledge and skills are important, the ability to work in cooperative networks is almost always twice as critical to achieve success [6–8].

Among several reasons, what makes organizations engage in cooperative networks with other organizations such as business partners, institutions, or universities, just to name a few, is the possibility they have to access the necessary resources (human, competencies, financial, logistic and so on) to properly respond to the increasing and complex market demands [8]. However, research shows that despite the benefits that cooperative networks can bring to organizations, such as the open innovation model [9], they are not engaging in it as much as it would be expected [10]. According to several literature reviews, the reason for such a trend is the lack of effective and efficient supportive models to manage such partnership types [8,11,12].

This work presents a heuristic model that aims at the efficient management of organizational cooperative networks, as a contribution to reduce the lack of existing supportive models to manage organizational cooperation. The proposed heuristic model, named MCPx (which stands for management of cooperative projects) was developed based on four essential scientific pillars: (1) project risk management, (2) cooperative networks, (3) social network analysis, and (4) business intelligence, as illustrated in Figure 1.

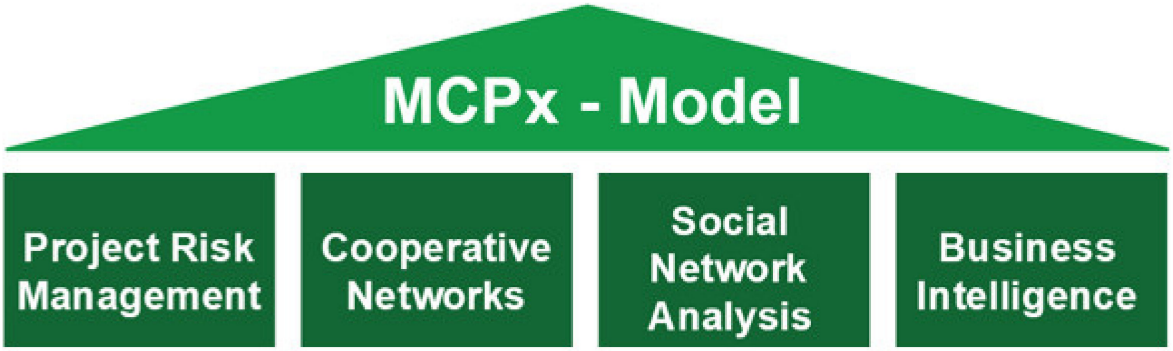

Figure 1. The four critical scientific pillars that support the MCPx model.

Concretely, the MCPx model quantitatively measures five key project cooperative behavioral dimensions as they emerge, develop and eventually disappear or continue within a bounded period of time, within a project social network. The five key project cooperative behavioral dimensions are: (1) communication, which identifies who communicates with whom related to project information, (2) information sharing, which identifies who shares with whom project-related information, (3) trust, which identifies who trusts whom regarding delicate project subjects, (4) problem solving, which identifies whom people go to in order to get support, advice or project-related information so that they can do their job, and (5) decision making, which identifies who usually makes decisions regarding project-related tasks and activities. Table 1 illustrates the individual contributions of each one of the four critical scientific pillars that support the development of the proposed model in this work.

Table 1. Four critical pillars that support the development of the MCPx model.

Scientific Pillars	Brief Description Regarding Individual Contributions
Project Risk Management	Contributes with the definitions and structure of a typical project (lifecycle, phases, and so on) according to the Project Management Institute [13], and with the definitions and approach process of the risk management standard process according to the International Organization for Standardization [14].
Cooperative Networks	Contributes with the definitions, importance, and key factors regarding cooperation principles between organizations. This work assumes the cooperative principle of performing joint work according to [11].
Social Network Analysis	Provides the tools and techniques (essentially centrality metrics such as in-degree, out-degree, density, average degree, closeness and so on, based on the graph theory) which will quantitatively measure the five key project cooperative behavioral dimensions that emerge and evolve as organizations cooperate to deliver projects.
Business Intelligence	Contributes with the typical organizational business intelligence architecture (collecting, transforming, analysing data and reporting) that enables organizations to perform business data analysis in a timely and accurate manner so that they can take more data-informed decisions.

1.1. Relevance and Novelty of the Conducted Research in This Work

The research conducted in this work addresses the problem of the lack of effective models to manage cooperation between organizations while they deliver projects. The research conducted in this work resulted in a heuristic model that contributes to answer the following research question: To what extent does cooperation between organizations that work together across all the phases of a project lifecycle impact project tasks and activities, and ultimately the global project outcome?

Having the research question along this line of thought, it can be concluded that the proposed model in this work directly addresses organizational cooperative project risks, namely behavioral cooperative risks, as mentioned before. The relevance of the conducted research in this work can be divided into four different dimensions.

First, and as the main objective of the research conducted in this work is the development of a heuristic model (the MCPx model), to help organizations to identify and efficiently manage cooperative project risks that may emerge as different organizations work together (cooperate) to deliver projects, by analyzing five key project cooperative behavioral dimensions across all the phases of a project lifecycle as mentioned before. This will enable organizations to clearly see how cooperation (behaviors) unfolded, and how they are unfolding, and to a certain extent predict how cooperation will evolve in the near future, based on the quantitative analysis of past collaborative initiatives. The benefit for organizations is that they can implement proactive actions (corrective or supportive measures) to reorganize and redirect cooperation to a desired level, and/or support and maintain existing cooperative behavioral patterns. This first dimension enabled by the proposed model in this work is in line with the latest research in the organizational management field that argues that first, cooperative networks supported by effective management models provide organizations strong benefits at both individual and collective levels [2,6–8], and second, that the adoption of a more hands-on management style (more control from the management regarding how cooperation emerges or evolves) in opposition to a more hands-off approach management style (less control from the management regarding how cooperation emerges or evolves, also known as a fix-it-as-you-go issue resolution approach), is by far more beneficial to increase the chances of success [6,15].

Second, the proposed model in this work enables organizations to quantitatively measure dynamic cooperative behaviors regarding five cooperative dimensions: (1) com-

munication, (2) information sharing, (3) trust, (4) problem solving and (5) decision making, as mentioned before. This allows organizations not only to in a timely manner identify which behaviors may possibly turn into a risk (threats to project objectives) but also to take decisions in a more data-informed way (which are decisions that can be backed up with data that can be verified [16], instead of only relying on subjectivity (usually from senior managers) and gut feelings approaches, which, according to research, increases organizational performance and profitability [17,18].

Third, by applying the theory of social network analysis to analyze and monitor dynamic cooperative behaviors, the MCPx model is in line with the latest research in the social sciences that argues that the application of SNA metrics is by far the most appropriated technique to mirror human interaction and thus extract valuable and unique insight regarding how dynamic interactions between entities across a bounded period of time emerge and evolve [8,19–22].

Fourth, the proposed model in this work is efficiently aligned with the actual sustainability challenges and with the ongoing organizational transformation strategy and industry 4.0, according to research [23,24]. This happens as the model enables the identification of organizational cooperative behavioral patterns in a secure and timely manner supported by an intelligent system (business intelligence architecture) which automates the process of data collection, analysis, and reporting, resulting in huge resource savings. Still, this aspect contributes to solve the information modeling and processing as indicated by latest research [25]. By doing so, the proposed model in this work focuses not only on the short-term results, but also in the long-term results, enabling sustainability in organizations to turn into a holistic, consistent, and incremental growth process across time according to the following value-chain: the identification of (undesired or desired) organizational cooperative behaviors in a timely manner enables organizations to better respond to ongoing and future cooperative project challenges, which in turn optimizes allocation of necessary resources for ongoing or upcoming projects, which in turn will contribute to a leaner organizational and societal transformation, providing organizations sustainable competitive advantages in the economic, social, and environmental aspects.

1.2. Structure of the Present Work

This work is divided into seven sections. In Section 1 a brief introduction regarding the purpose of the research conducted in this work, its importance, and its relevance are presented. Section 2 presents a brief state of the art regarding the four critical scientific pillars that support the proposed model in this work. Section 3 presents the development and implementation of the proposed model in this work, where the four scientific pillars that support the proposed model will be addressed, highlighting the individual importance and contribution of each one of them to the proposed model. Section 4 presents an application case of the proposed model. Section 5 presents the major conclusions of the conducted research in this work, highlighting some of the benefits and limitations of the proposed model in this work. Section 6 presents the academic and managerial implications regarding the implementation and application of the proposed model in this work. Finally, in Section 7 we present a set of suggestions for future developments regarding the research conducted in this work.

2. Literature Review

2.1. Project Risk Management

The successful delivery of projects is critical for organizations because it is through projects, but not only, that organizations can execute their strategies, solve problems, satisfy needs, add value, capitalize on or exploit opportunities, adapt, change, learn, and innovate [2,8,13].

A project can be defined as a temporary endeavor with a defined start and end, and aims at the creation of a unique result, product, or service [13]. Project management can be defined as the application of knowledge and techniques to project activities across the

different phases of a project lifecycle, aiming at the successful delivery of a project within the specific project constraints [13].

Risk management, in a general form, can be defined as a set of coordinated activities to direct and control an organization regarding risk [13,14]. Risk has two dimensions: (1) a positive dimension, usually called opportunities, and (2) a negative dimension, usually called threats [13,14]. Risk management can be defined as a combined and continuous process of decision analysis and proactive management, that should be taken as an integrative part of the organizational governance, design, structure, strategy, change, and culture of an organization [26,27]. Still, risk management should be supported, incentivized, and not policed, by internal or external experts to the organization [26,27].

Putting together the definition of project management and risk management, we can define project risk management. Project risk management results from the intersection between project management and risk management and can be characterized by the introduction of the best practices and standards regarding risk management into project management [28]. From this intersection new project risks types emerge. According to [28] there are four major project risks that result from the intersection between project management and risk management. They are: event risk, variability risk, ambiguity risk, and emergent risk. They are illustrated in Table 2.

Table 2. Four major project risks types according to [28].

Risk Types	Brief Description	Recommended Management Approach
Event Risk	Also known as "stochastic uncertainty", these are risks that relate to something that has not yet occurred, but if it comes to occur, will impact on one or more project objectives.	Risk Management Standards tools and techniques.
Variability risk	Also known as "aleatoric uncertainty ", comprising different possible known outcomes, but no one knows which one will really occur.	Advanced tools and techniques such as the Monte Carlo simulation.
Ambiguity risk	Also known as "epistemic uncertainty ", emerging from lack of knowledge or understanding (also called of know-how and know-what risks). These risks comprise the use of new technology, market conditions, and competitor capability, just to name a few.	Lessons learned (learning from experience). Simulations and prototyping.
Emergent risk	Also known as "ontological uncertainty "or "Black Swans", these are risks unable to be identified because they are just outside one's experience or mindset. Usually these types of risks arise from game-changers or disruptive innovations.	Contingency planning.

Beyond the four major project risks types proposed by [28], research identifies also other risks in project management, such as cooperative risks that can emerge as organizations work together to deliver projects [29]. According to [29], such cooperative project risks can be classified in three different dimensions. They are: (1) behavioral risks, which

represent risks related to the different types of relationships that are established between the different organizations or entities while they work together (cooperate) to deliver a project, (2) risk of assigning tasks to partners, which represent risks that result from how project tasks and activities are distributed by different organizations or network partners, and (3) risk of critical enterprises, which represents risks that are associated with cooperative network members who have exclusive competencies or resources.

The proposed model in this work will specifically address the behavioral risks in project management environments, which can be characterized by the way that different project stakeholders interact (exchange project-related emails, exchange project-related information, search for advice or support related to project matters, or general communication, just to name a few) within a bounded period of time (usually a project lifecycle phase). More concretely and as mentioned before, such behavioral risks will be identified and characterized by analyzing the five key project cooperative behavioral dimensions: (1) communication, (2) information sharing, (3) trust, (4) problem solving, and (5) decision making.

2.2. Cooperative Networks

The cooperative form of business has been around for more than 150 years [30]. However, this form of doing business has never remained constant throughout the years, varying between economic sectors, countries, and cultures [30]. Effective cooperation between organizations contributes to a higher ability to adapt to changes in the environment where they exist, enables a strategic position concerning inter-organizational networks, and assures flexibility when facing changes in the environment [31].

Cooperative networks can be defined as networks that comprise a variety of entities such as organizations, groups, people, or others, that exchange information, adjust activities, and share resources for the achievement of compatible goals [11]. For example, in a traditional supply chain network based on client–supplier where the interactions are coordinated with each other, there is in most cases no common goal, rather mutual benefits and a common plan which often is designed by a single entity [11]. Still, this form of doing business implies a certain division of labor among participants where the resulting aggregated value comes from the sum of a quasi-independent manner from individual value-generated contributions [11]. According to research [11,30,32], efficient organizational cooperative networks strongly depend on factors such as the reliance of the cooperative on reciprocity (information that is exchange in both directions between any two organizations), trust and interlocking directorates (where a member of one organization's board of directors also serves on another organization's board or within another organization's management positions).

In this work the factors that characterize cooperative networks (aggregated value coming from the sum of individual contributions, reciprocity, trust, and more) will be addressed by the MCPx model. Such factors will be addressed as the MCPx model analysis of how the different project stakeholders interact by analyzing the already mentioned five key cooperative behavioral dimensions, which mirror some of the factors that characterize the form of joint work named cooperative networks.

2.3. Social Network Analysis in Organizations

Social network analysis (SNA) can be defined as a theoretical framework for modelling dynamic interactions between entities (persons, groups, organizations, and so on), that reveal how social structures emerge, evolve, disappear, and influence individual behaviors and vice versa across a period of time [20,21,33]. SNA quantitatively describes social structures by analyzing the interactions of entities that are within a given social structure (social network) [20,21]. In SNA entities are conceptualized as nodes or dots which in turn are linked by edges that represent their interactions [20,21,33]. The result of the conceptualization is a graph (social network) that is then analyzed using network-theoretic concepts also known as SNA metrics or measures [20,21,33]. SNA plays a critical role in understanding social capital challenges, and therefore is being continuously incorporated

into organizational risk management departments as a supportive tool for decision making and risk analysis [8,34].

In project management the application of SNA has been growing in popularity within the latest years, essentially because it enables people to understand in a quantitatively way the extent to which project people and project organization behaviors impact on performance, innovation, social cohesion, information diffusion, trust, and so on [20,21]. Still, SNA in project management can be applied to study cooperation, collective and individual performance, cultural fit, unethical behavior, and fraud, just to name a few [35].

Across the reviewed literature there are many successful cases of the application of SNA in project management. For example, researchers applied SNA to identify key cooperative networks that emerge as organizations work together while delivering projects [8,19–21,36]. Some of them are as follows: (1) communication network (identifies who talks to whom regarding work-related matters), (2) advice network (identifies the people to whom others turn to, to get information to get their job done), and (3) trust network (identifies who shares project-related delicate information with whom).

Cross and Parker [36] applied SNA in organizations to study how dynamic cooperation emerges, evolves, and disappears as different organizations work together while delivering a project, and identified a set of key informal roles that exist within a cooperative network regardless of an organization's structure or industry type. They are: (1) central connectors (represents central people or organizations that too many rely on for help, advise, trust, or other), (2) boundary spanners (represents people that connect different organizational pockets or departments, which sometimes are also called of information brokers), (3) peripheral people (represents experts, or isolated people or organizations, which may either be a SME (subject matter expert) with unique exerts, or a mis-fitted person or organization), and (4) energizers (represents people or organizations that energize a group or the complete cooperative network).

Researchers such as [20,21,37] suggest that social network centrality metrics such as in-degree, out-degree, average degree, betweenness degree, closeness degree, and eigenvector, are among most meaningful SNA centrality metrics that can be applied in organizations to identify valuable and unique insights, regarding how dynamic cooperation evolves across time.

Furthermore, they argue that the application of SNA centrality metrics in the analysis of dynamic cooperative networks are the ones that enable us to get unique insights, unlike traditional tools or techniques [2,8,20,21]. According to the reviewed literature, centrality in a social cooperative network refers to the structural location of a given entity within a network, and can be a measure of an entity's influence, importance, control, and prestige [20,21,37]. Research shows that. for example, both in and out degrees can be an index of potential for the network's activity, betweenness can be an index of communication control by bridging two different subgroups of a network, and closeness can be an index of the potential independence from network control [2,8,38,39].

Centrality is associated with the mix of formal and informal power within a cooperative social network [2,8,38,39]. This happens because according to several pieces of research, it is extremely difficult or impossible to distinguish formal from informal networks of cooperation within an organization [2,8,20]. All previous mentioned centrality metrics, but not only those, quantitatively capture an amount of a certain cooperative behaviors that ultimately will impact on project activities, objectives, and outcomes (success or failure) and therefore should not be neglected [2,8].

In this work the application of SNA will quantitatively measure the mix of formal and informal cooperative networks which will enable the characterization of the five key project cooperative behavioral dimensions ((1) communication, (2) information sharing, (3) trust, (4) problem solving, and (5) decision making). More concretely, the characterization of the five key project cooperative behavioral dimensions will be done by the application of SNA centrality metrics such as weighted total-degree, average weighted, total-degree, in-degree, and average in-degree.

2.4. Business INTELLIGENCE in Organizations

Business intelligence (BI) can be defined as a set of strategies, concepts, methods, and technologies that are applied by organizations for the data analysis of business information to improve business decision-making processes [39–42]. A typical BI architecture comprises a set of tools, methodologies, systematic processes, and frameworks, that collect, analyze, and transform—from both, internal and external sources—data into insightful, valuable, actionable, and meaningful information, which organizations can use to understand past, actual, and future business trends such as consumer behavioral patterns, or to efficiently support organizations in strategic decision-making processes [40–42]. An efficient BI architecture implies a dynamic organizational interconnected communication network, where information that is produced or acquired (both internal and external regarding sales, finance, human resources, engineering, marketing, just to name a few) can be easily accessed and readable [42]. Figure 2 illustrates a typical business intelligence architecture.

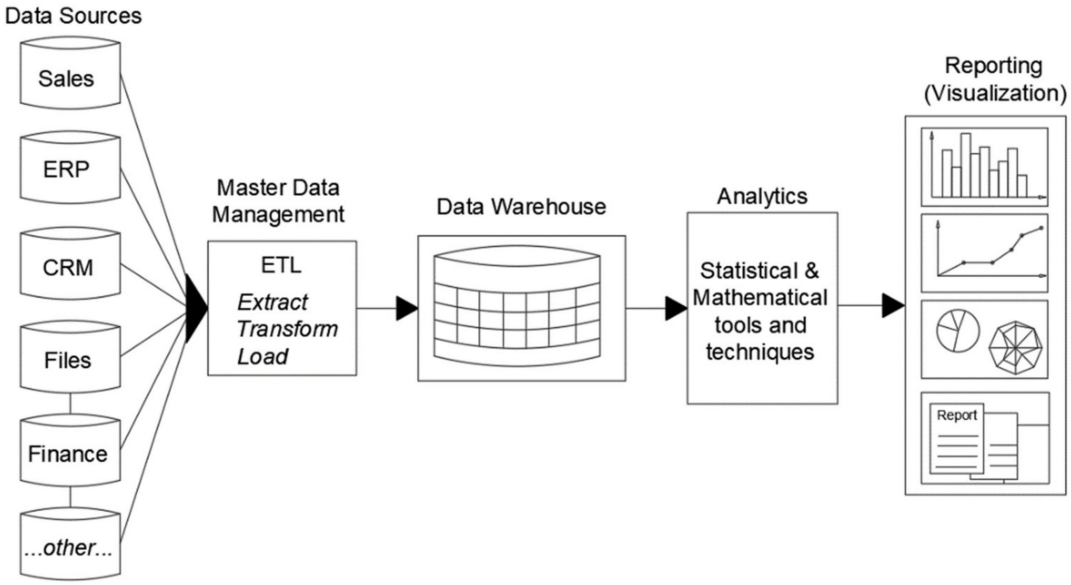

Figure 2. Typical business intelligence architecture. Adapted from [40–42].

The process starts from left to right according to the arrows of the flow diagram, and goes across some of the major components such as data sources, data management systems, data warehouses, business analytics tools and techniques, and reporting or visualization tools and techniques.

The working process of the typical BI architecture displayed in Figure 2 goes as follows: First, data are collected from a given data source such as sales or finance departments, ERP systems, CRM systems, single files, or engineering departments. Second, collected information undergoes a data treatment process which very often is called ETL (extract, transform, and load data process). In this process, collected data from the most varied data sources are cleaned and transformed into a readable format according to user needs. Third, treated data are stored in data warehouses, which are considered as the BI component's heart. A data warehouse is built with the purpose to serve the data analysis and reporting components, where only data from the ETL process are loaded [42]. Data warehouses are built on normalization standards, which are efficient for transactional systems [41,42]. For example, a normalization could be used to reduce redundancy and increase performance of queries for reports and analytics. BI systems and tools make use of data warehouses as sources of information to generate reposts and analysis. Fourth, collected, treated, and stored data will be qualitatively and quantitatively analyzed by the application of statistics and mathematical analytical tools and techniques. In this step three types of analytics are common [43]. The first, descriptive analytics, comprises the process of analyzing the past

data. This means analyzing data from sales, marketing, or other areas, that were collected, treated, and stored into a data warehouse. The purpose of this first analysis is to understand what happened, or in other words, to identify the root causes for occurred business outputs and outcomes. The second, predictive analysis, concerns the process of estimating the likelihood of future business outputs and outcomes based on the analysis of past data. It is also known as a trend analysis [41,42]. The third, prescriptive analytics, concerns the process of finding ways and means to take advantage of findings acquired in the previous two analytical processes, and generate predictions about future events or trends. This process is usually carried out by using simulation techniques based on inferential statistic and computerization techniques [40]. Finally, the reporting and visualization BI system outputs information that can be readable in an efficient way enabling the connection of analyzed data to business strategies. In this stage, the results of the data analytics process can be visualized through several different methods such as strategic and tactical dashboards, scorecards, CSFs (critical success factors), KPIs (key performance indicators), and detailed or consolidated reports [42]. The proposed model in this work comprises the incorporation of a typical BI architecture in an automatic, efficient, accurate and timely manner to collect, prepare, transform, and analyze cooperative project data that mirror cooperative dynamic behaviors within a project social network, that takes place across the different phases of a given project lifecycle.

3. Model Development and Implementation

3.1. Model Development

As previously mentioned, the proposed model in this work developed based on four critical scientific pillars ((1) project risk management, (2) cooperative networks, (3) social network analysis, and (4) business intelligence), will analyze in a quantitative way how five key project cooperative behavioral dimensions ((1) communication, (2) information sharing, (3) trust, (4) problem solving and (5) decision making) emerge and evolve across the different phases of a project lifecycle, as different organizations work together to deliver cooperative projects. The four critical scientific pillars that support the development of the model proposed in this work are illustrated in Figure 3.

Figure 3 illustrates the four critical scientific pillars that support the development of the proposed model in this work: (1) project risk management (a), (2) cooperative networks (b), (3) social network analysis (c), and (4) business intelligence (d). A brief explanation of each of them is as follows:

Project Risk Management (Figure 3a)—this pillar can be divided into two sub-pillars: project management and risk management. The project management field provides the proposed model in this work with the definitions and structure of a typical project according to the Project Management Institute (PMI) [13]. These include the definition of a project, project phases, project lifecycle, project specific attributes and features, and so on. The risk management field provides the proposed model in this work with the definitions and approaches regarding the risk management standard processes according to the International Organization for Standardization (ISO) [14]. It covers the process of identifying, analyzing, measuring, treating, monitoring, and updating project risks. The risk management sub-pillar still contributes with three project major risks types that may emerge as organizations work together to deliver projects, as proposed by [29] (Figure 3a). They are: (1) pure risk or uncertainty, (2) project risks, and (3) cooperative risks. In this work, the cooperative risks will be addressed as the major project risk type, and in particular the behavioral risk types as illustrated in Figure 3a. As mentioned before, behavioral risk types are related to the types of dynamic relationships that are established between the different project partners across the delivery of a project.

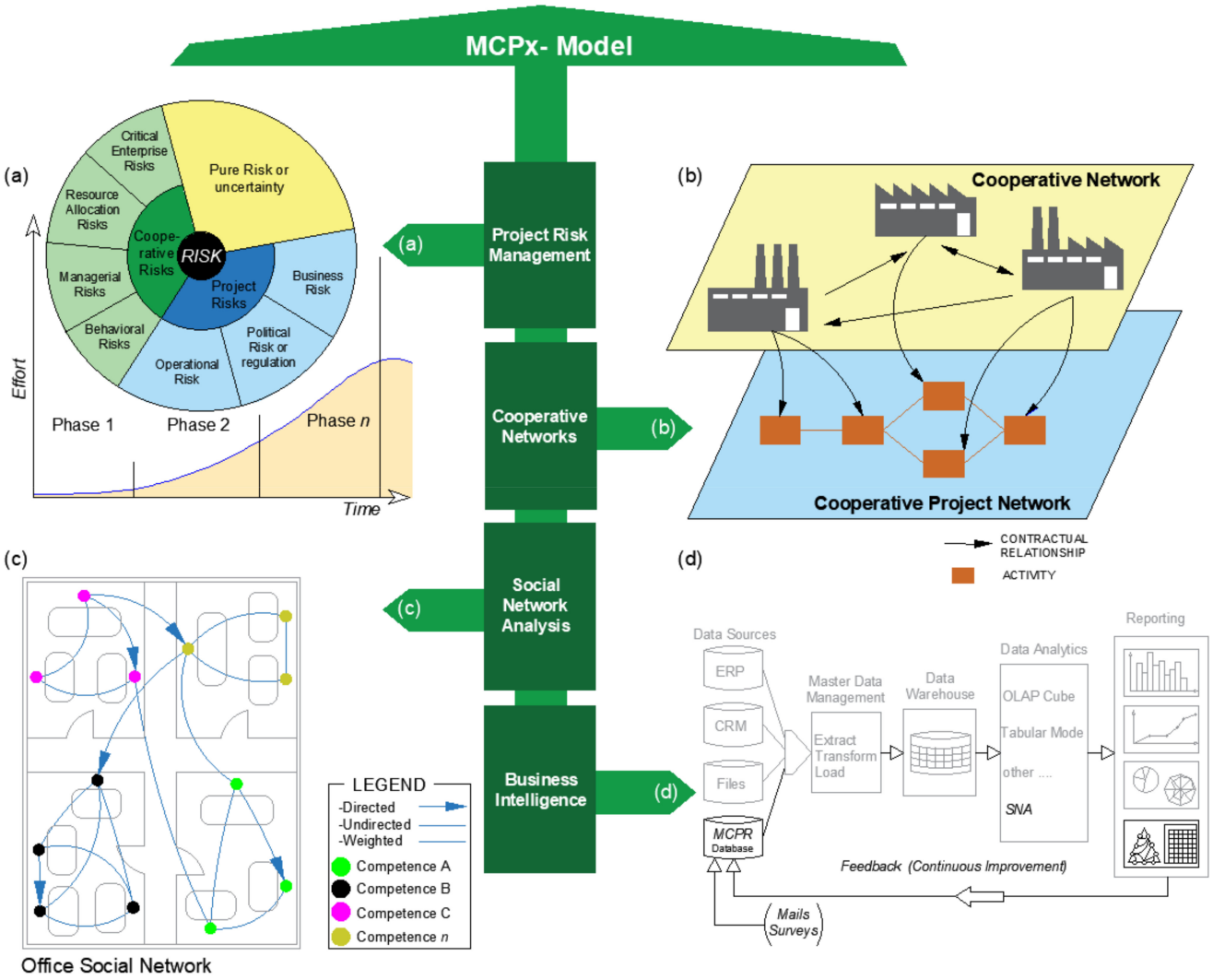

Figure 3. Detailed view of the four critical scientific pillars used in the development of the MCPx model, (**a**) project risk management pillar, (**b**) cooperative networks pillar, (**c**) social network analysis pillar, and (**d**) business intelligence pillar.

Cooperative Networks (Figure 3b)—this pillar contributes the definitions, key factors that determine and define cooperation, and the importance of cooperation between organizations to achieve project success. As illustrated in Figure 3b, this pillar contributes to the translation from the official dynamic interactions from the upper layer where cooperation exists between organizations (which represents contractual relationships) into visible and measurable dynamic interactions that truly mirror the different interactions, behaviors, and dependencies among organizations that deliver projects in cooperative networks.

Social Network Analysis (Figure 3c)—this pillar contributes the tools and techniques to quantitatively analyze dynamic behavioral interactive data that takes place across the different phases of a project lifecycle as project stakeholders (people, groups or organizations) work together to deliver projects. SNA centrality metrics developed based on the graph theory (Figure 3c) are applied to quantify the five key project cooperative behavioral dimensions ((1) communication, (2) information sharing, (3) trust, (4) problem solving and (5) decision making), that evolve across all the different phases of a cooperative project lifecycle. This pillar provides the proposed model in this work the SNA centrality metrics such as in-degree, out-degree, total-degree, and total weighted-degree [37] which will quantify the five key project cooperative behavioral dimensions. Once the five key project cooperative behavioral dimensions have been quantified, conclusions regarding cooper-

ative project behavioral risks can be outdrawn together with a social network analyst or with a project responsible team.

Business Intelligence (Figure 3d)—this pillar contributes the strategies and technologies, that organizations can use to analyze business information data and get unique and actionable business insight. This pillar provides the proposed model in this work the implementation steps of a typical organizational BI architecture, as well as the dynamic articulation between the different stages of data analysis, namely in three mentioned analysis types: (1) descriptive analyses (which, referring to data analysis, aims to answer questions such as what happened? how did we get here?), (2) predictive analysis (which based on analyzed data aims to answer questions such as where are we possibly heading to? what will happen in the future according to a given trend?), and (3) prescriptive analysis (which based on the other two analysis, aims to answer questions such as what should we do to get to a certain target?).

As previously mentioned, the proposed model in this work quantitatively analyses five key project cooperative behavioral dimensions that emerge and evolve as projects are being delivered by the joint work (cooperation) of different organizations.

To map, quantify, and analyze each one of the five key project cooperative behavioral dimensions-specific data, specific SNA centrality metrics are required as illustrated in Table 3. Table 3 illustrates the five key project cooperative behavioral dimensions (D1 to D5), the data sources for each of the five key project cooperative behavioral dimensions, the objectives of each of the five dimensions, and the SNA centrality metrics that are applied to quantify the five key project cooperative behavioral dimensions.

The required data to map and analyze the five key project cooperative behavioral dimensions will be collected by two methods: (1) cooperative project-related exchanged emails, and (2) cooperative project strategic surveys. The first method concerns the collection of information project-related emails within a given interval between *t_1* and *t_n*, within a given project lifecycle. The second method concerns the collection of project-related information through the launching of a SNA strategic survey to all the cooperative project stakeholders that take part in the delivery of a cooperative project. The questions in the survey are not pre-determined, however they must capture valuable and unique information that enables the mapping of the different cooperative dimensions or networks. The questions are to be decided by a network analyst or the project responsible team. For example, regarding the information-sharing dimension (D1), one possible question could be, to whom do you go to get project-related activities or tasks information? Or, with whom do you share project-related information with on a daily basis? For example, for the decision-making dimension (D4) one possible question could be, who decides what to do regarding your project tasks or activities? Or, whom do you go to get approval regarding your project tasks or activities?

Table 3. MCP model´s social betwork analysis centrality metrics.

Networks or Dimensions (D)	Data Sources	Objectives and Applied SNA Centrality Metrics	
D1: Communication	**Emails**: All exchanged email data between all organizations that participated in the different phases of a cooperative project lifecycle. This project-related information is to be collected at the end of each project timing t.	SNA Metric 1: Weighted Total-Degree $$C_{WTD}(n_i) = \sum_j x_{ji}$$ where: C_{WTD} = total weighted degree of an entity within a graph n = total number of entities within a graph for $i = 1 \ldots, n$ xji = number of all links (non-directional) and their weight from entity j to entity i, or vice-versa, where $i \neq j$. Objective 1: Identify who is more or less central and who is more or less peripherical in the project email exchange network.	(1)
		SNA Metric 2: Average weighted total-degree $$C_{AWTD}(n_i) = \frac{\sum_j x_{ji}}{n}$$ where: C_{AWTD} = average total weighted degree of an entity within a graph n = total number of entities within a graph for $i = 1 \ldots, n$ xji = number of all links (non-directional) and their weight from entity j to entity i, or vice-versa, where $i \neq j$. Objective 2: Map the evolution across the different project phases of the project communication network.	(2)
D2: Information sharing	**Survey**: Addressed to all organizations that participated in the different phases of a cooperative project lifecycle. This project-related information, is to be collected in each project timing t.	SNA Metric 3: In-degree $$C_{ID}(n_i) = \sum_j x_{ji}$$ where: C_{ID} = total degree of an entity within a graph n = total number of entities within a graph for $i = 1 \ldots, n$ xji = number of links (directional) and from entity j to entity i, where $i \neq j$. Objective 1: Identify who provides more or less advice regarding project information related.	(3)
		SNA Metric 2: Average In-degree $$C_{AID}(n_i) = \frac{\sum_j x_{ji}}{n}$$ where: C_{AID} = Average In- degree of an entity within a graph n = total number of entities within a graph for $i = 1 \ldots, n$ xji = number of links (directional) and from entity j to entity i, where $i \neq j$. Objective 2: Map the evolution across the different project phases of the information sharing network.	(4)

Table 3. Cont.

D3: Trust	**Survey**: Addressed to all organizations that participated in the different phases of a cooperative project lifecycle. This project-related information is to be collected in each project timing t.	SNA Metric 1: In-degree (see (3)). Objective 1: Identify who is more or less central within the project trust network. It maps the trust network and identifies who discusses in confidence sensitive information and ideas, and to whom. SNA Metric 2: In-degree (see (4)). Objective 2: Map the evolution across the different project phases of the trust network.
D4: Problem solving	**Survey**: Addressed to all organizations that participated in the different phases of a cooperative project lifecycle. This project-related information is to be collected in each project timing t.	SNA Metric 1: In-degree (see (3)). Objective 1: Identify who are the organizations that belong to a given project problem solving network. It maps the problem-solving network and identifies who knows what and how. SNA Metric 2: In-degree (see (4)). Objective 2: Map the evolution across the different project phases of the problem-solving network.
D5: Decision making	**Survey**: Addressed to all organizations that participated in the different phases of a cooperative project lifecycle. This project-related information is to be collected in each project timing t.	SNA Metric 1: In-degree (see (3)). Objective 1: Identifies who are the decision-making organizations with the cooperative project network. SNA Metric 2: In-degree (see (4)). Objective 2: Map the evolution across the different project phases of the decision-making network

As it can be seen in Table 3 for each of the five key project cooperative behavioral dimensions, two SNA centrality metrics will be applied. For D1, the first metric concerns the identification of who is more or less central within a given project cooperative dimension, and the second metric concerns the evolution of a given dimension across the different phases of a project lifecycle by analyzing the average results of the cooperative project social network of the first metric applied. For example, for D1, the first metric is the weighted total-degree. This metric is non-directional (it does not matter who sends what to whom or who received what from whom) and maps the email communication channels within a cooperative project social network, and the number of emails that are comprised in each one of the email communication channels. For example, if a cooperative project social network has 7 organizations that work together in a given project lifecycle the n = to 7, which represents the number of organizations. If for example, project-related emails have only have been exchanged between organizations 1, 2, and 3, the number of email communication channels will be three (xji). This represents the number of links as illustrated in Table 3. The number of project-related exchanged emails within each of the three email communication channels, will give the respective weight of each communication channel. For example, if in the email communication channel 1 there were exchanged 50 project-related emails, then the weight of this email communication channel would be 50. For D1, the second metric, average weighted total-degree, is the simple average from the results of applying metric 1, weighted total-degree. For D2, the first metric, in-degree, regards the identification of who is more or less central in the information sharing network within the cooperative project social network. This metric is a directional metric, and takes into consideration the direction of the links from j to i, which in this case represents a preference or choice. For example, to map this network the required data arrives through a cooperative project survey that is launched to all entities (people, groups, or organizations) that are involved in the delivery of a cooperative project. The survey contains one or more questions that strategically target the required data to match the information sharing network. There are many different ways to formulate a question in such cases. For example, in this case the question could be: to whom do you go to get project-related information that helps you to do your work? Or still, with whom do you

share with critical project-related information? The question could be still more specifically formulated, and target a specific subject as, for example: with whom do you share critical project-related information related to activity [name of activity]? Once data regarding the answer of the cooperative strategic project survey are collected, the information-sharing network can be mapped. In this case, each project stakeholder has nominated one or more project stakeholders as being the one that they share information with, or go to to get information from. Each given nomination from a project stakeholder to another project stakeholder is an outgoing link towards the nominee, where in turn, the nominee gains an in-link, which in other words, represents an in-degree of value 1. For D2, the second metric, average in- degree, is the average of the total number of in-links of each one of the cooperative project stakeholders, that were nominated in the information-sharing network. The same principle is applied for dimensions D3, D4, and D5, as illustrated in Table 3.

3.2. Model Implementation

The implementation of the MCPx model adopts the PMI´s project structure and definitions as is illustrated in Figure 4. Figure 4 illustrates a generic cooperative project lifecycle according to the PMI [13] project management standards, which is constituted by several different project phases that range from phase I up to phase *n*.

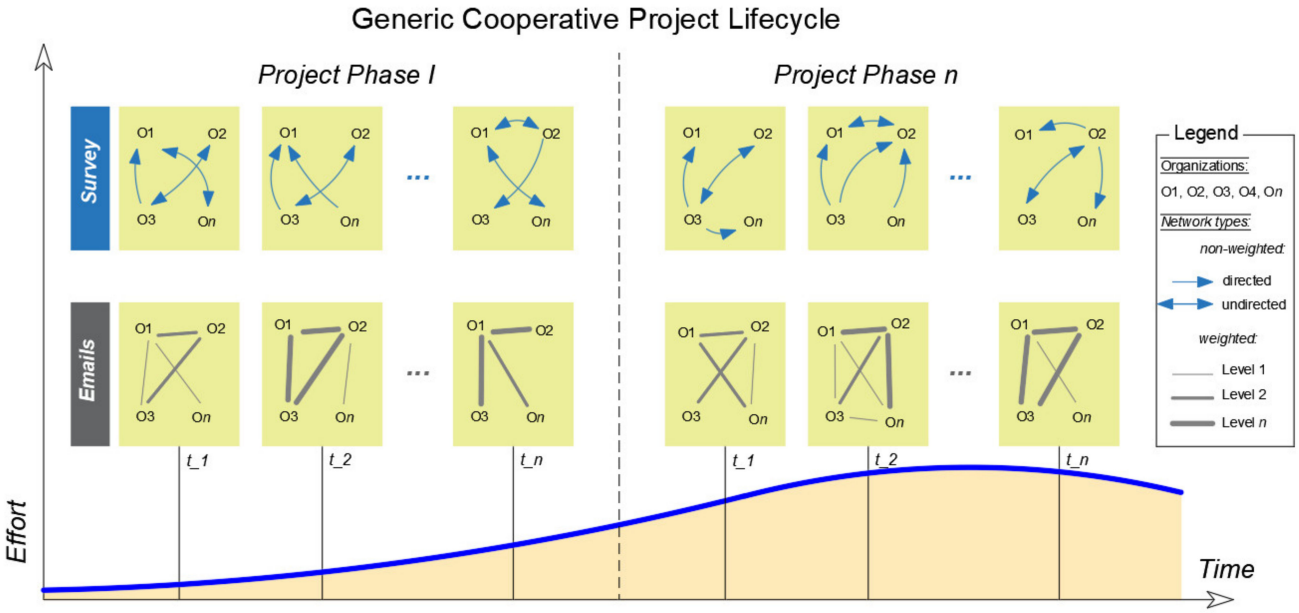

Figure 4. Implementation framework of the MCP model.

In each project phase are defined a set of project times that range from *t_1* to *t_n*. The number of project times *t* is totally customizable and represent the times where project data are collected and analyzed. As mentioned before, data sources are exchanged project emails and strategic project surveys, as is illustrated in Figure 4 in grey and blue boxes, respectively. For example, in phase I two project times are defined as *t_1* to *t_2*. For *t_1*, in the emails row, the graph or network inside the yellow box represents a given email communication network. In this case there are four different organizations, O1, O2, O3, and O*n*. The links between the four organizations represent the number of mails that have been exchanged between the four organization within the period from *t_1-1* and *t_1*. The links between organizations are weighted links and must be interpreted with the help of the legend illustrated at the right side of Figure 4. For example, between organization O1 and O2, the link represents a level 2 link. The levels in the legend of Figure 4 represent a quantity class of project exchanged emails, which also is fully customizable. For example, in phase I, between organizations O2 and O*n*, in time *t_1* in the emails row, there is no link between them. This means that within the period from *t_1-1* and *t_1*, no project emails

were exchanged between these two organizations. The links in the email communication network are undirected links. This means that the links have no particular direction. It means only that there have been emails sent from O1 to O2, and/or from O2 to O1.

Still in phase I in the survey row in project time *t_1* is represented by the survey network. This network is a directed network, which means that the links between the different organizations have a direction. It means that the links are born of a function of nominations from one organization to another organization or organizations. For example, O1 has two in-links that come from organizations O3 and O*n*. This means that for a given survey question launched, organizations O3 and O*n* nominated O1.

For example, if the survey question was 'from whom do you go to get advice or support regarding project tasks or activities?', it would mean that organizations O3 and O*n* have nominated O1 as the organization to go to in order to get support or advice for their project tasks and activities. In the case illustrated in the survey row for *t_1*, applying (3), the in-degree metric according to Table 3, organization O1 would get a value of two for the in-degree metric, and all the remaining organizations would get a value of one for the in-degree metric. This process is to be repeated in all the project times *t_n*, in all the different phases of a project lifecycle.

As mentioned before, the proposed model in this work is incorporated into a typical business intelligence architecture, in order to automatize and enhance the capabilities of the above illustrated process (which fairly describes the proposed model in this work). The integration of the proposed model in this work into a typical organizational BI architecture is illustrated in Figure 5.

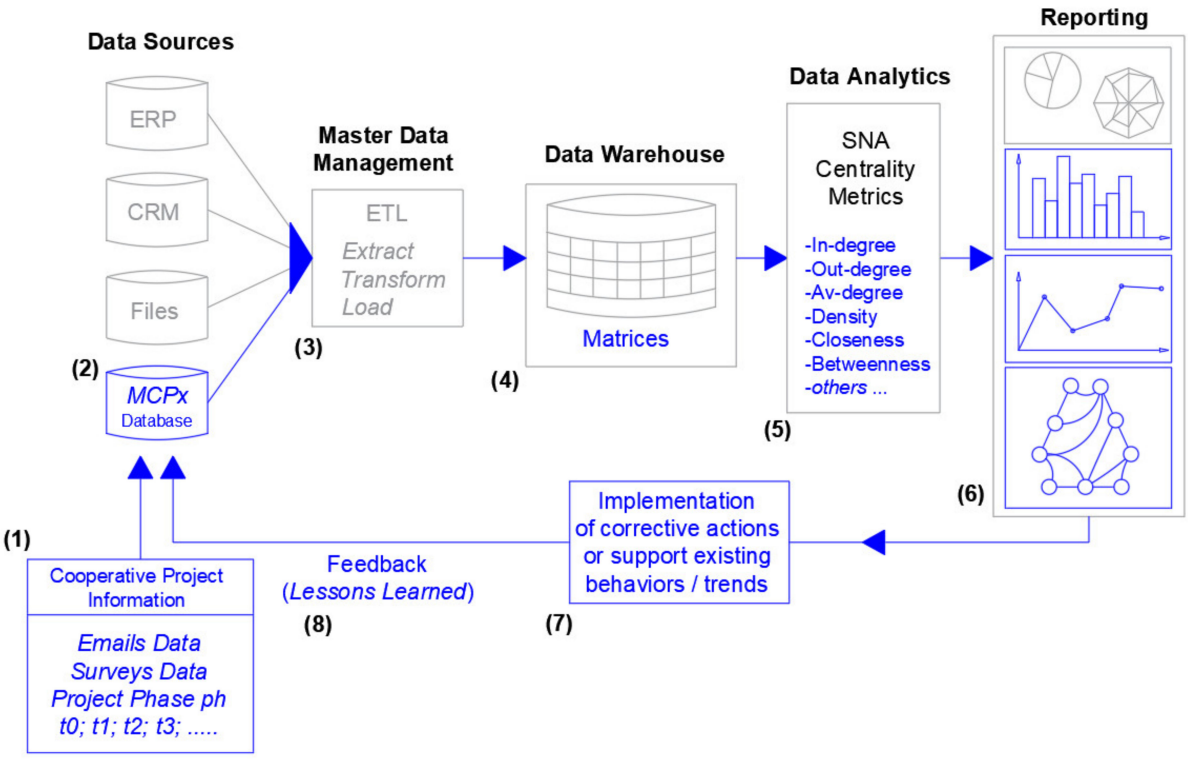

Figure 5. Integration of the proposed model in this work in a business intelligence architecture.

Figure 5 illustrates a typical organizational business intelligence architecture adapted from [40–42], and the respective integration of the proposed model in this work illustrated in blue. The integration process can be described as follows: First, (1) information from the two mentioned sources (project emails and project surveys) regarding cooperative projects is collected in each project time *t_n*, and in each of the different phases of a cooperative project lifecycle. Second, collected data are stored in a temporary data base (2), which is a dedicated database to the proposed model in this work (the MCPx model). Third (3),

collected data undergo a process of extraction and transformation, which represents the cleansing and translation of collected information in surveys and project emails stored in the dedicated database (MCPx Database). Fourth, (4) treated data (cleaned and transformed) are stored in a master database (data warehouse) in an appropriated and readable form. In this case data are stored in a matrixial form. Fifth (5), to the collected and transformed cooperative project data, several SNA centrality metrics such as in-degree, average degree, density and so on, (essentially SNA metrics based on graph theory) and statistics will be applied, in order to quantitatively analyze the five key project cooperative behavioral dimensions, which in turn will enable to quantify cooperative project risks. Sixth (6), the results of the application of SNA centrality metrics and statistics to cooperative project data will be displayed in a form of chart bars, trends, and graphs. The next step (7) comprises the decision-making phase where decision makers supported by the results outputted by the proposed model in this work will implement measures or actions either to change the direction of the ongoing organizational cooperative dynamic behaviors, or to support it towards the end of a given project phase. Finally (8), after a cooperative project has been accomplished, cooperative project lessons learned should be collected and added to the MCPx model´s database, to refine the overall process of data collection, treatment, and analysis. This could include for example the reformulation of some survey questions to get more insight regarding the different five cooperative dimensions that emerge and evolve across all the different phases of a project lifecycle

4. Application of the MCPx Model—A Case Study

4.1. Introduction to the Application Case

The following case study illustrates part of an extensive application of the proposed model in this work (the MCPx model) in the management of cooperative projects behavioral risks that was conducted by a market leader Food and Beverage company (denominated in this case study as organization 1) in mid-Europe across the year 2020. Organization 1 launched a project offer (denominated in this case study as project 1) to 7 other organizations from different areas that include mechanical installations, automation, processing engineering, and so on. Project 1 comprises the implementation of a new cheese production line to be executed in a period of 12 months. After analyzing the individual project proposals of each of the 7 organizations, organization 1 decided to go further with the execution of project 1, hiring organizations 2 and 3. All organizations accepted to take part in the case study which implies the application of the proposed model in this work. The case study consists of the application of the MCPx model across all the different phases of the lifecycle of project 1 in order to identify and monitor cooperative dynamic behavioral patterns that may threat the success deliver of project 1.

More concretely, the objective of the case study is to analyze the evolution of the five key project cooperative behavioral dimensions ((1) communication, (2) information sharing, (3) trust, (4) problem solving and (5) decision making) across the different phases of project 1´s lifecycle, and how these may evolve towards corporative project risk. Across this section of the present work, an extract of the case study conducted in phase II of project 1, and some major conclusions, will be presented. The analysis process that goes from the data collection, data extraction and transformation, application of SNA centrality metrics, and statistics until the reporting phase conducted in this case study, was supported by the integration of the proposed model in this work into an organization business intelligence architecture as illustrated in Figure 5. For this matter, a dedicated project mailbox (including mail server and accounts) was created where all the participating organizations in cooperative project 1, exchanged all project-related information across all the phases of the cooperative project 1's lifecycle.

The project 1 surveys addressed to all the participating organizations in the cooperative project lifecycle were done through an online platform, where participants were asked to provide answers to the project survey questions. Both the dedicated project mailbox and the online platform were where project 1 participants answered project surveys, representing

the MCPx database as illustrated in Figure 5 (2). Both project-related email data exchanges and project survey answers were collected at pre-defined times *t* within each of the different phases of the project lifecycle.

Once data were collected, it immediately underwent a transformation process by the application of an algorithm, which essentially transformed collected data into several quantitative matrixes. Next, the data were quantitatively measured by the application of SNA centrality metrics (weighted total-degree, average weighted total-degree, in-degree, average in-degree) as illustrated in Table 3. The final step performed by the business intelligence architecture is the output of weighted and undirected and directed graphs, as illustrated in Figure 6 in the next sub-chapter (4.2 Application of the MCPx model).

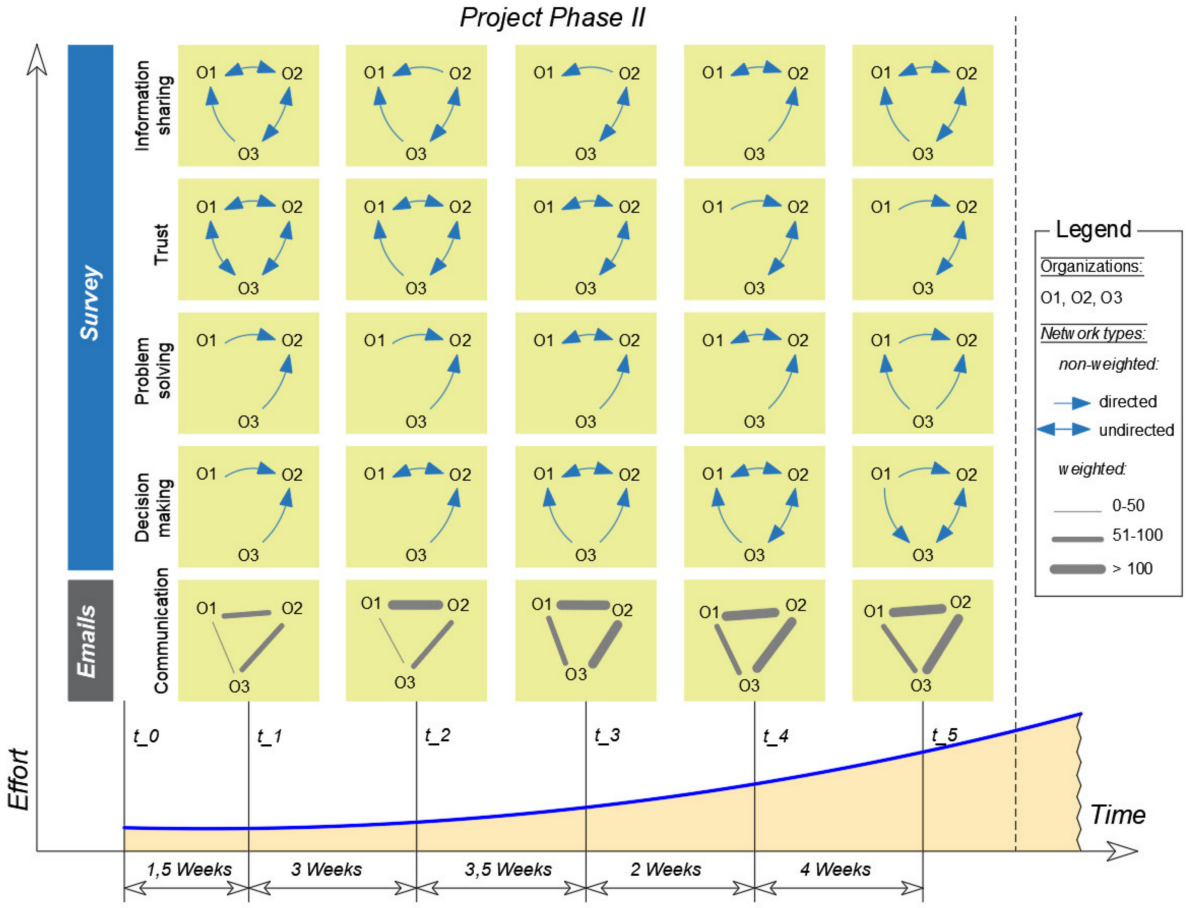

Figure 6. Application of the MCPx model to the planning phase of a cooperative project.

4.2. Application of the MCPx Model

Figure 6 illustrates the results in the form of a network of the application of the SNA centrality metrics to project 1 data collected in project 1 emails and project 1 surveys, between the period *t_0* and *t_5* in the planning phase (phase II).

The dimension´s results illustrated in Figure 6 represent the sum (regarding the communication dimension) and the average (regarding all the survey dimensions) results, from the analysis of all participants' exchanged emails and answered surveys, from organizations 1, 2, and 3, which were constituted by 9, 12, and 6 project people, respectively.

To map the email network exchange in Figure 6, all project-related exchanged emails within the period between *t_0* and *t_5* in each project time *t_n*, were collected and analyzed. To map the four different project survey networks, data from project surveys were collected and analyzed.

As it can be illustrated in Figure 6, the time between any two-given *t*s is not constant. For example, between *t_1* and *t_2* there were 3 weeks of time elapsed, and between *t_3* and *t_4* there were 2 weeks of time elapsed.

The first dimension to be analyzed is the communication dimension between the period *t_0* and *t_5*. In Figure 7 (communication in-degree evolution between *t_1* and *t_5*) and Figure 8 (communication average in-degree evolution between *t_1* and *t_5*), are illustrated the results of applying (1) and (2), according to Table 3, respectively, to the communication dimension illustrated in Figure 6.

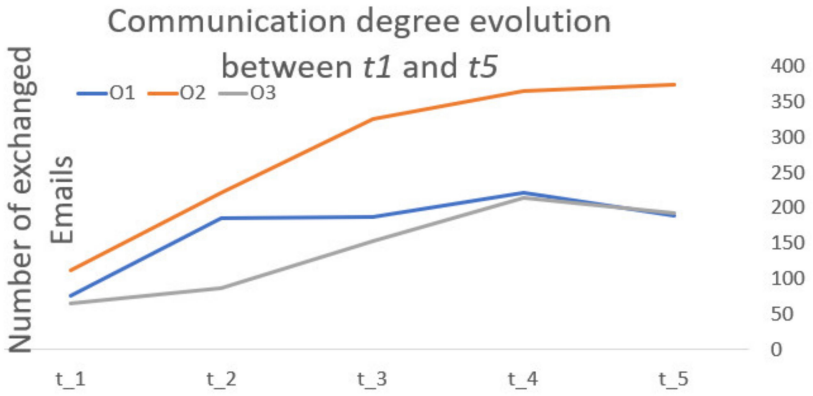

Figure 7. Communication in-degree evolution between *t*_1 and *t*_5.

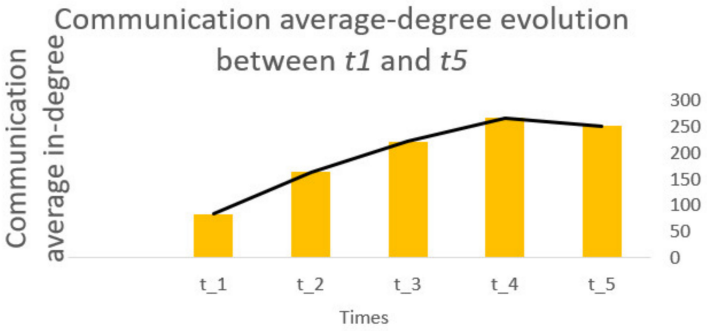

Figure 8. Communication average in-degree evolution between *t*_1 and *t*_5.

As it can be seen in Figure 7 regarding the communication degree evolution between *t_1* and *t_5*, there seems to be a certain balanced evolution regarding all the three organizations O1, O2, and O3. Nevertheless, organization O2 experienced a continuous increase from *t_1* until *t_5* regarding the email communication network. This immediately means that a substantial quantity of project-related emails were not shared with organizations 1, and 3. This trend can represent that, especially from *t_2* onwards, that organization O2 has gained a substantial control over the email or communication network, when compared to the other two organizations. In fact, it almost doubled its size or domination, specially from *t_3* onwards. This behavior could be a signal of a certain tendency to a future of an unbalanced communication network in the upcoming project phases.

Furthermore, this behavior is to a certain extent clear, when analyzed regarding the trend in the period between *t_4* and *t_5* regarding organizations 1 and 3 (which have a clear negative slope), while organization 2 is still increasing. Finally, the behavior illustrated in Figure 7 may represent a project cooperative behavioral risk, in the sense that it may lead to a large difference between organization 2 and organizations 1 and 3, regarding the amount of project-related information that flows across the email communication network. This could still be translated into poor communication and ultimately result in poor performance.

Figure 8 illustrates the evolution of the communication network regarding the average in-degree (or total-degree, once the email communication network is a non-directional network) between *t_1* and *t_5*. As it can be observed the average trend is in line with what is observed in the individual trends in Figure 7. This represents that regarding the communication network there was a clear increase of exchanged project-related emails as the project moves along the time axes in phase II. However, between *t_4* and *t_5*, there can be observed a negative tendency which is affected by the abrupt decrease of emails sent and received from Organizations 1 and 3 in the respective period of time.

Figure 9 (Information sharing in-degree evolution between *t_1* and *t_5*) and Figure 10 (Information sharing average in-degree evolution between *t_1* and *t_5*) illustrate the results of applying (3) and (4) according to Table 3, respectively, to the information sharing dimension illustrated in Figure 6.

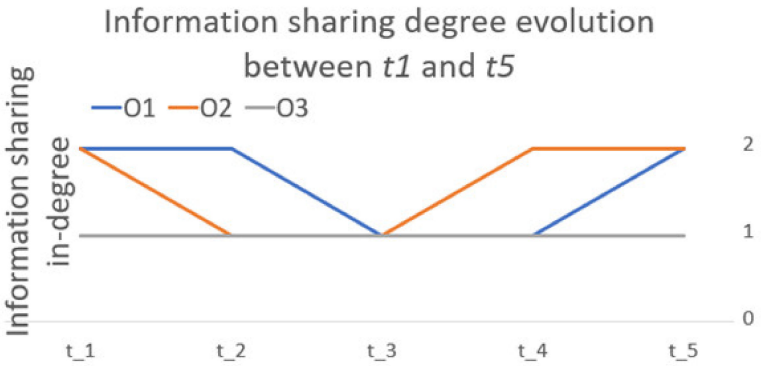

Figure 9. Information sharing in-degree evolution between *t*_1 and *t*_5.

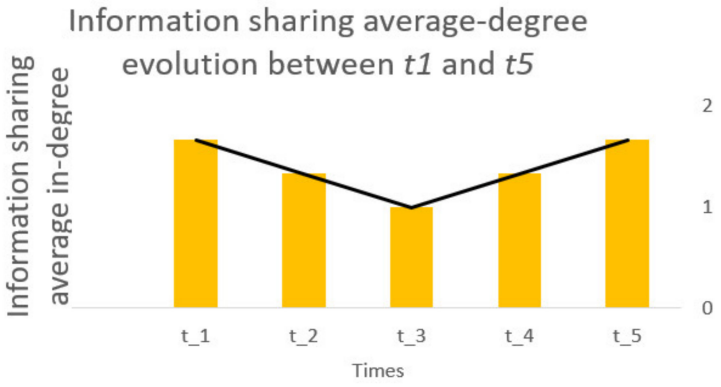

Figure 10. Information sharing average in-degree evolution between *t_1* and *t_5*.

To map the information sharing dimension illustrated in Figure 6 the following question was addressed to the elements of the three organizations that work together in cooperative networks across phase II of project 1: *who shares or updates you with relevant project-related information on a regular basis?* As it can be seen in Figure 9 regarding the information sharing in-degree, all three organizations have very different behaviors across the period *t_1* to *t_5*. For example, organization 1, between *t_1* and *t_2* starts to share a high volume of information, however, after *t_2* until *t_4*, it seems to have experienced an abrupt decrease in sharing project-related information with the other two organizations. Organization 2 presents a similar behavior as organization 1, but this occurs before organization 1. This behavior may reflect an action–reaction dynamic type explained by the reaction of organization 1 to the behavior of organization 2. Such behavior may be explained as follows: As organization 2 decreases the amount of information shared across the planning phase of project 1 between *t_1* and *t_2*, organization 1 gets awareness of that behavior and replicates in the same way. The inverse is also observed as organization 2 increases the

sharing amount of project-related information from *t_3* onwards. The observed behavior illustrated in Figure 9 regarding organizations 1 and 2 may reflect a certain risk regarding the relationships between them, that can be translated into a certain insecurity regarding a particular project subject or subjects, in both organizations almost simultaneously.

On the other hand, organization 3 has had a stable behavior across the same period, regarding the amount of shared project-related information.

Figure 10 illustrates the average in-degree for the information sharing dimension. The evolution of this dimension also clearly reflects the change in behavior from organizations 1 and 2. This evolution may to a certain extent represent project delay risks, namely in time *t_3*, as organizations 1 and 2 coincide regarding the amount of shared project-related information. Such cooperative project risks may occur because some project tasks or activities may suffer some delay as organizations are waiting to get input from how the project is evolving.

Figure 11 (trust in-degree evolution between *t_1* and *t_5*) and Figure 12 (trust average in-degree evolution between *t_1* and *t_5*) illustrate the results of applying (3) and (4) according to Table 3, respectively, to the trust dimension illustrated in Figure 6.

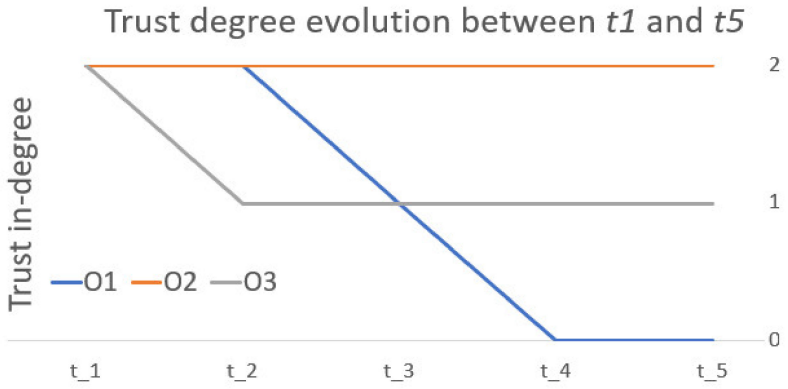

Figure 11. Trust in-degree evolution between *t_1* and *t_5*.

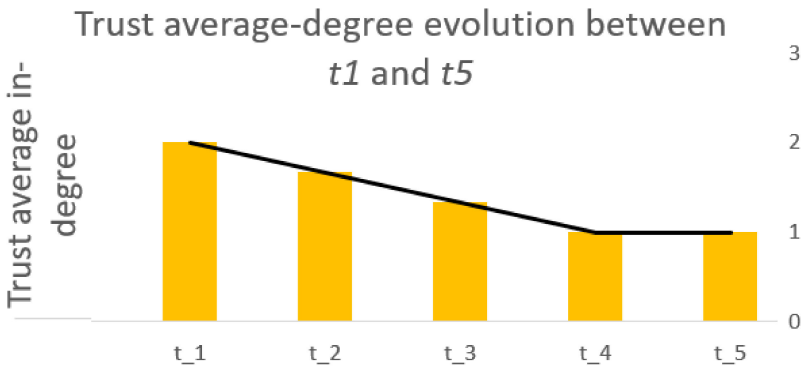

Figure 12. Trust average in-degree evolution between *t_1* and *t_5*.

To map the trust dimension illustrated in Figure 6, one question was addressed to the elements of the three organizations that worked together in cooperative networks across phase II of project 1. The question was: *whom do you trust in to talk about project issues or optimizations within fearing a certain retaliation?*

As it can be seen in Figure 11 there are very different evolutions between *t_1* and *t_5* regarding the three participating organizations. However, organization 2 has a constant behavior across the analyzed period of time when compared with the other two organizations. This immediately represents that both organizations 1 and 3 highly trust organization 2 when it comes to project-related issues or new ideas. However, the trust level decreases as the project evolves across the phase II towards organizations 1 and 3. One particular

aspect can be observed in the behavior of organization 1. According to the evolution of the trust level of organization 2 illustrated in Figure 11, from time *t_2* onwards organization 2 constantly keeps losing trust within the project social network, reaching an absolute zero vale from *t_4* onwards. This clearly means that organization 1 has lost some credibility as the project evolves in phase II. This fact may be a consequence from what is observed in the evolution of the information sharing degree in Figure 9, where organization 1 seems to have followed or retaliated to the behavior of organization 2 regarding the amount of shared project-related matter.

As trust is one of the most important aspects in cooperative projects as mentioned in Section 2.2 Cooperative Networks, it can be concluded that project 1 tasks and activities may be negatively impacted by the trust dimension within phase II. This behavior can be further investigated by analyzing the average in-degree trust evolution between *t_1* and *t_5* in phase II of project 1, as illustrated in Figure 12. On average, the trust level within the project social network which is comprised by the members of organizations 1, 2, and 3 drops exactly to half from *t_4* onwards, of the value observed in *t_1*. In this case, project managers and leaders should adopt measures to reestablish the necessary trust level within the project social network, so that the dynamic cooperative interactions get back to a desired level, and thus enhance the chances to achieve a successful project outcome for project phase II and onwards.

Figure 13 (problem solving in-degree evolution between *t_1* and *t_5*) and Figure 14 (problem solving average in-degree evolution between *t_1* and *t_5*) illustrates the results of applying (3) and (4) according to Table 3, respectively, to the problem-solving dimension illustrated in Figure 6.

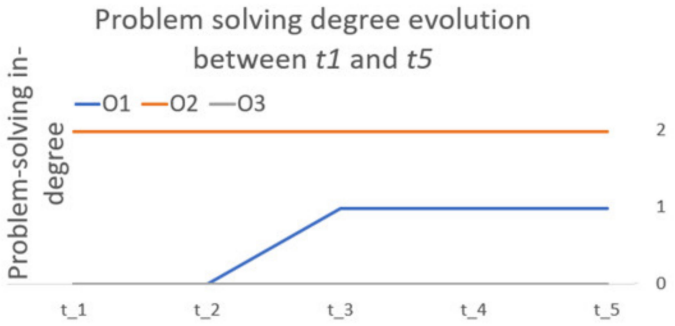

Figure 13. Problem solving in-degree evolution between *t_1* and *t_5*.

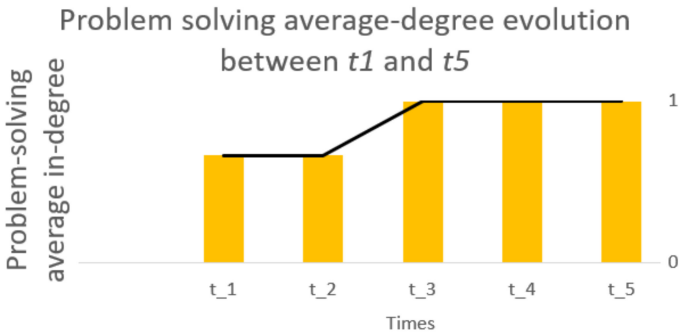

Figure 14. Problem solving average in-degree evolution between *t_1* and *t_5*.

To map the problem-solving dimension illustrated in Figure 6, one question was addressed to all elements of the three organizations that worked together in cooperative networks across phase II of project 1. The question was: whom do you turn to, to get effective help concerning your project tasks or activities?

As it can be seen in Figure 13 all three organizations have distinct behaviors regarding the problem-solving network across the analyzed period between *t_1* and *t_5* of project

1 in phase II. As in the previous analysis regarding the trust dimension in Figure 11, organization 2 has a constant evolution across the analyzed period, hitting the highest rate possible. This means that organization 2 is the organization whom the other two organization go to, to get expertise or relevant know-how or know-what regarding project tasks or activities. Both trust and problem-solving dimensions, concerning organization 2, places organization 2 in a particular important position within the project social network of project 1 in phase II. According to the results illustrated in Figures 11 and 13, organization 2 is the organization on which the other two (organizations 1 and 3) strongly and steadily rely on when it comes to trust and problem-solving dimensions.

When analyzed together, i.e., the trust evolution in Figure 11 with the problem-solving evolution in Figure 13 for organization 2, one can immediately conclude that organization 2 has a central role within the mix of formal and informal project 1 social relationships. This may eventually turn into a problem at the long run, while in the short run may be a precious help for the development of project 1 in phase II. This could be explained as follows: If organizations 1 and 3 increase the level of dependence on organization 2 as being the one to go to to get help regarding project-related matters, it may lead to the emergence of bottlenecks and delays, as organizations 1 and 3 wait from support of organization 2. In this case it can be said that project 1 in phase II faces simultaneously two cooperative project behavioral risks. The first risk regards to risks associated to the assignment of tasks to project partners which can be divided into two sub-dimensions. The first sub-dimension concerns organizations that have disproportionate know-how and know-what levels when compared with other organizations. This may represent that there is a risk when assigning certain tasks or activities to cooperative project partners in the sense that they will not execute those activities or tasks without help from another organization or organizations. This may contribute to the non-compliance with project deadlines, milestones and so on, while simultaneously, the second dimension will overload other organizations with excessive help requests, leading to the emergence of bottlenecking, delays, or burn-outs, and ultimately will negatively impact project 1 objectives. The second risk regards the risk of critical enterprise which is characterized by having project partners within a cooperative network that have exclusive competencies, know-how, or know what. This may lead to the same already mentioned non-compliance outcomes, but also to the emergence of a non-healthy cooperative environment among the organizations that participate in a cooperative project.

Such a non-healthy cooperative environment may be characterized by the non-intentional relaxing of some partners regarding going to others (concerning the execution of project tasks and activities, but not only), where continuously more output is expected than would be expected and rational.

On the other hand, organization 3 has never been nominated as being an organization with problem-solving skills according to evolution of the problem-solving in-degree illustrated in Figure 13. It can be clearly seen that regarding this dimension (problem solving) organization 3 has a peripherical position within the project social network. In the context of phase II of project 1, putting together the four analyzed dimensions (communication, information sharing, trust, and now problem solving) it can be said that organization 3 shows indices of poor integration within the project social network. This may represent that there is a certain distance regarding cooperation between organization 3 and the other two organizations in phase II of project 1, between *t_1* and *t_5*. These suspicions outdrawn by the analysis on project 1 behavioral data, should be cleared through follow-up interviews to access more accurately what might be going on regarding the cooperation between the three organizations that work together to deliver project 1 across phase II. However, Figure 14 shows that the average degree of the problem-solving network has increased between *t_2* and *t_3* and remained constant from *t_3* onwards. The increase observed in Figure 14 between *t_2* and *t_3* is due to the increase problem solving in-degree of organization 1, which rises one degree between the same period.

Figure 15 (decision-making in-degree evolution between *t_1* and *t_5*) and Figure 16 (decision-making average in-degree evolution between *t_1* and *t_5*) illustrate the results of applying (3) and (4) according to Table 3, respectively, to the decision-making dimension illustrated in Figure 6.

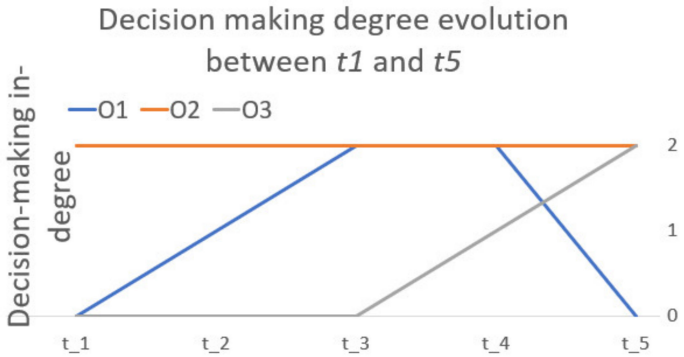

Figure 15. Decision-making in-degree evolution between *t_1* and *t_5*.

Figure 16. Decision-making average in-degree evolution between *t_1* and *t_5*.

To map the decision-making dimension illustrated in Figure 6 the following question was addressed to the elements of the three organizations that work together in cooperative networks across phase II of project 1: *who most decides what, when, and how to execute project tasks or activities?*

As it can be seen in Figure 15, organization 2 has once again a position of relevance within the decision-making dimension. While organization 2 has a constant evolution across the period between *t_1* and *t_5* of project 1 in phase II, organizations 1 and 3 have a variable behavior regarding the decision-making dimension. The evolution of the decision-making dimension illustrated in Figure 15 may represent a certain competition level between organizations 2, 1, and 3, but not between organizations 2 and 3. This can be explained as follows: According to Figure 15 the observed trend of organization 1 (increase in its importance regarding the decision-making dimension between the period *t_1* and *t_3*) can be explained by the behavior observed in Figure 13 regarding the problem-solving dimension of organization 1. As organization 1 increases its importance in the problem-solving dimension, it simultaneously increases its position in the decision-making dimension. This occurs because these two dimensions (problem-solving and decision-making), are to a certain extent related—the one who knows, is often the one who decides.

However, organization 1 does not go far, and after reaching the top regarding the decision-making dimensions between *t_3* and *t_4*, it abruptly drops to a zero level in *t_5*, which to a certain extent is related to the loss of trust, observed between *t_4* and *t_5*, as illustrated in Figure 11, in the trust in-degree evolution dimension. Organization 3 on the other hand, even without having scored in the problem-solving dimensions, seems to benefit from the continuous lack of trust regarding organization 1 observed in Figure 11, while simultaneously holding a constant position within the project social network regarding the trust dimension. Finally, Figure 16 shows the average evolution of

the decision-making in-degree between *t_1* and *t_5*, and shows that the decision-making dimension suffers a slight increase between *t_1* and *t_4*, which essentially reflects the evolution of organization 1 between the same period. Nevertheless, the decision-making dimension illustrated in Figure 16 has a positive evolution across phase II of project 1 between *t_1* and *t_5*. This may be explained as follows: The observed trend may indicate a certain volatility regarding who is who and who plays what in the project 1 social network. This could mean that as the project 1 phase II evolves, the degree of power (in a mix of both formal and informal) across all participating organizations also evolves (increases). This trend may represent a certain lack of direction, or "holding command" risk regarding how this is being managed. However, the observed trend may still indicate a certain increase of empowerment of the organizations that cooperate in the delivery of project 1, which may be beneficial for the project in terms of finding new solutions, ideas, and a more flexible approach regarding change.

After the application of the MCPx model which enabled us to quantitatively analyze the five key project cooperative behavioral dimensions across phase II of project 1, project 1 top managers and/or project 1 leaders are now better informed (more data-informed) about the potential risks that such observed cooperative behaviors may comprise in the successful delivery of project 1. Finally, after conducting strategic follow-up assessments on those particular observed behaviors (trends) identified by the MCPx model, project 1 top managers and/or project 1 leaders can now properly develop better data-driven strategies to efficiently manage the analyzed five key project cooperative behavioral dimensions, and therefore increase the likelihood of project 1′s successful delivery.

5. Conclusions

This work presents a heuristic model that in a quantitative way analyzes the mix of formal and informal networks of relationships between organizations that work together (cooperate) to deliver projects by analyzing five key project cooperative behavioral dimensions, (1) communication, (2) information sharing, (3) trust, (4) problem solving and (5) decision making, that usually take place in cooperative projects. One advantage of the proposed model in this work is the analysis of the interaction between entities in a cooperative project environment which can be represented as single persons, groups, or entire organizations, as is the case in the presented case study. Another advantage of the proposed model in this work is that it can be scalable, without suffering any type of influence in the analysis process as it scales up. This happens because the proposed model is not affected by any type of estimation as, for example, the R2 value in linear regression calculations. The mathematical approach of the proposed model deals only with absolute results (pure quantitative results). Nevertheless, if there are a huge number of entities to be analyzed it is recommended to use indexation (ranging from 0 to1) instead of absolute numbers in the outputted results scale. As it has been seen across the case study, the application of the proposed model in this work is simple and straightforward. The same is to be said in relation to the results outputted by the proposed model. However, it is recommended that the interpretation of the results outputted by the application of the MCPx mode should be done by professionals in the social network analysis area. Furthermore, the results outputted by the MCPx model regarding the quantitative identification of cooperative behavioral trends or patterns should always be succeeded by follow-up assessments in order to clearly and accurately identify the real reasons and potential impacts of such behaviors or trends on project tasks and activities.

6. Academic and Managerial Implications

6.1. Proposed Model and Academic Implications

The developed research across this work culminated in a heuristic model (the *MCPx* model) developed based on four critical scientific pillars ((1) project risk management, (2) cooperative networks, (3) social network analysis, and (4) business intelligence architecture) to efficiently support the management of project cooperative risks by analyzing five

key project cooperative behavioral dimensions. By doing so, the proposed model in this work contributes to create knowledge to manage cooperative risk projects, namely in the behavioral risks field as is illustrated in Figure 3a. The developed research across this work aims to contribute to each of the four critical scientific pillars that were used to develop the proposed model in this work in a holistic and interrelated way. This way, the relationships between concepts of project management, risk management, collaborative networks, social network analysis, and business intelligence become clearer and build the foundations to further research, as in each one of them is the context of the management of cooperative projects. In the pillar of the project risk management, the proposed model in this work contributes to a holistic, deeper, and accurate understanding of how cooperation really emerges and evolves across the different phases of a cooperative project lifecycle, and how such evolution may or may not be originating behaviors that to a certain extent represent cooperative risks to project activities and ultimately project outcome. This in turn may enable the development of new theoretical approaches regarding how to manage a project's cooperative risks. In the cooperative networks pillar the proposed model in this work contributes to identify other factors (such as problem solving, information sharing, decision making and so on) besides trust, reciprocity, and interlocking of directorates, which can play a central role for an efficient and effective cooperative project network. In the pillar of SNA in organizations the proposed model in this work contributes to the development of new insights and discoveries regarding the importance and implications of the different mix of formal and informal cooperative project roles (identified by the application of SNA centrality metrics) within a project social network. Finally, in the business intelligence pillar the proposed model in this work contributes to the understanding of how organizations can benefit from the implementation of a BI architecture in boosting their organizational components and to better see the interrelations between areas such as risk management and human resource management, which could generate the development of new organizational theory, namely concerning the way cooperative work gets done in organizations in modern times.

6.2. Proposed Model and Managerial Implications

The proposed model in this work efficiently helps organizations in managing cooperative project risks as illustrated across the case study presented in this work. The application of the MCPx model enables organizations to, in a timely manner, and in an effective and quantitative way, access the variability evolution of the dynamic interactions (cooperative behaviors) that emerge and evolve among participants in cooperative projects. This in turn will enable organizations to take and implement actions to readjust undesired or support desired cooperative project behaviors before they turn into real project risks.

The ability to quantitatively measure the different cooperative behaviors that occur across the different phases of a project lifecycle enables organizations to take more data-informed decisions, rather than relying too heavily on gut feelings and on subject matter experts or even on influential opinions from people/organizations, which many times advise without having a sustainable quantitative basis, where, even worse than that, more often than not such advice is strongly biased.

The integration of the MCPx model into a BI architecture provides organizations accuracy, speed, and efficiency in identifying (most often hidden) cooperative behaviors across the different phases of a project lifecycle that emerge from the mix of formal and informal relationships. Furthermore, the integration of the MCPx model in a business intelligence architecture can be considered an intelligent predictive model. This happens if a substantial number of past projects are analyzed and a function of repeatable observed behaviors associated with certain project outcomes, a cooperative project critical success factor, can be identified. Then, such cooperative project critical success factors can be replicated in future cooperative projects and used as guides to manage future cooperative projects.

Finally, the proposed model in this work helps organizations to, in a smarter and faster way, address the ongoing organizational digital transformation and to pursue the actual

and upcoming sustainability challenges, in a holistic and consistent way by efficiently focusing efforts on the achievement of short- and long-term goals and ultimately in the generation of sustainable business.

7. Further Developments

The continuous development of new SNA centrality metrics as critical enablers of gaining a deeper insight regarding the dynamic interactions between organizations that participate in cooperative project networks is recommended. However, the application of other SNA metrics rather than centrality should be also tested. It is also recommended that the proposed model in this work should be improved upon to be able to distinguish pure formal from pure informal relationships in project environments. By doing so, it would be possible not only to accurately quantify how much do informal and formal networks of relationships exists in cooperative projects, but also to clearly measure the real importance of informal and formal networks in the management of cooperative projects. It would also enable us to accurately correlate the importance of informal networks and formal and informal power in a cooperative project environment.

It is also suggested that deeper research should be conducted in terms of gaining access to email content matter in order to better get more insights regarding how communication takes place, but also the quality of the communication. For this matter joint work with GDPR regulators should be conducted in order to create legal mechanisms to enable deeper access to information generated in the work environment.

Finally, the incorporation of AI (artificial intelligence) advanced techniques such as ML (machine learning) or NN (neural networks) in the proposed model in this work should be considered in order to generate unique and actionable knowledge in a 360-degree approach, and estimate future outcomes (predictions) based on the analysis of past collaborative trends.

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Creating Actionable and Insightful Knowledge Applying Graph-Centrality Metrics to Measure Project Collaborative Performance

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Abstract: Tools and techniques supported by math and statistics are often used by organizations to measure performance. These usually measure an employees' traits and states performance. However, the third type of data usually neglected by organizations, known as relational data, can provide unique and actionable insights regarding the root causes of individual and collective performance. Relational data are best captured through the application of graph-based theory due to its ability to be easily understood and quantitatively measured, while mirroring how employees interact between them as they perform work-related tasks or activities. In this work, we propose a set of graph-based centrality metrics to measure relational data in projects by analyzing the five most voted relational dimensions ((1) communication, (2) internal and external collaboration, (3) know-how exchange and informal power, (4) team-set variability, and (5) teamwork performance), in a survey conducted to 700 international project stakeholders in eight business sectors. The aim of this research is to tackle two issues in projects: First, to understand in a quantitative way how the project's relational data may correlate with project outputs and outcomes, and second, to create unique and actionable knowledge to help mitigate the increasing project failure rates. A case study illustrates the step-by-step application of the developed graph-based metrics as well as its benefits and limitations.

Keywords: project management; graph-centrality metrics; project outcome; project lifecycle; individual performance; collective performance; correlation

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1. Introduction

In almost every organization, parallel to the formal organizational chart, a different type of network naturally emerges and evolves, characterized by the mix of informal and formal relationships between employees [1–3]. According to several studies, such a mix is usually responsible for how work gets done in organizations [2–6].

Informal relationships, also known as informal organizational networks, are often hidden behind the typical organizational formal chart and can only be uncovered by the application of graph-based metrics [1–3,5]. Such a mix of formal and informal networks is also known as relational data [1,4].

Research shows that it is practically impossible to clearly distinguish the formal from informal relationships that exist within an organization's social network, however, because

informal relationships usually extrapolate the formal ones, the mix of formal and informal relationships is usually called informal relationships or informal networks [7,8].

Relational data can be collected through the application of strategic surveys, strategic observations, and consulting data logs [1,2]. It is measured by applying graph-based metrics, such as in/out or average degree, closeness, betweenness, just to name a few [1,5,9–11]. The results can then be used to evaluate individual and collective performance, among other important organizational factors [12,13].

According to several studies, graph-based network centrality metrics are those that provide the most valuable insights when analyzing organizational informal networks [1,2,9–12]. Such centrality metrics measure in a quantitative way how important a given entity or a group of entities (people, groups, or organizations) within a social organizational network are. This is measured by analyzing collaborative dimensions, such as information sharing, communication, know-how exchange, and problem-solving, among many others [10–13]. For example, in an organizational context, employee centrality is understood as the advantage of being in a position within the organization that is not far from everybody, and as a consequence of it, an employee tends to ear things first and faster than others, allowing that employee to get a deeper insight into what is going on around the organization [1,2]. Furthermore, research shows that the application of graph-based centrality metrics enables organizations to identify informal key players that highly impact an organization's outputs outcomes [7,13]. Such key informal players include: Central hubs—people that are highly connected within a social network, information brokers—people that connect different pockets of an organization, boundary brokers—people that bridge different organizations or departments, peripheral—people that are at the outskirts of a social network either because they are not well integrated or because they may have some kind of expertise that requires some kind of isolation, energizers/de-energizers—people that positively or negatively influence a team or a group regarding the execution of organization's tasks and activities for example [13,14].

Because it is hard to find something that is not somehow connected, it is critical for an organization to uncover such hidden relationships. The reason for this is that it enables organizations to take the appropriate measures in order to properly manage such hidden relationships and thus potentially boost their overall organizational performance by uncovering pain points and leveraging hidden critical connections and capabilities [1,7,13–16].

Centrality graph-based metrics can be divided into two major groups [9]. They are: (1) Node (individual), and net (2) work (collective). Node centrality metrics include, but not only, in/out/total, and average degree, closeness, betweenness, and clustering degree. Network centrality metrics include, but not only, average in-degree/out-degree/total-degree, density, distance, and average distance. However, many existing graph-based centrality metrics do not capture the evolution of relational data in project environments in isolation. For example, the in and out-degree metrics alone are not enough to explain correlations between complex relationships and project outputs and outcomes. Due to this reason, the development of new, or the adaptation of existing graph-based centrality metrics supported by other measuring tools and techniques, such as basic statistics, work more efficiently in identifying dynamic relationships between project outcomes and outputs and informal networks.

In this work, we propose a set of graph-based centrality metrics to quantitatively measure project relational data by analyzing five key relational dimensions (KRD) that will help organizations to measure individual and collective relational performance and understand the potential correlation between informal networks and project outputs and outcome. They are: (1) Communication, (2) internal and external collaboration, (3) know-how exchange and informal power, (4) team-set variability, and (5) teamwork performance). These five KRD result from a survey conducted with 700 international project stakeholders between 2018 and 2021, where participants were asked to name some of the most important project collaborative dimensions. The necessary data to build each one of the KRD can be collected through project surveys, project meetings, and consulting project logs.

The aim of this research is to simultaneously tackle two issues in project management. First, to understand in a quantitatively way how projects' informal relationships may be correlated with project outputs and outcomes, and second—as a direct consequence of the analysis –, provide a complementary contribution to help understand the still increasing project failure or challenge rate as shown by some of the most internationally renowned project institutes, such as the PMI (project management institute) and the Standish Group [17–19].

This work is divided into six sections. In section one, a brief introduction is presented to highlight the importance of quantitatively measuring relational data in organizations and the main objectives of this research. Section 2 presents an extensive literature review on state of the art regarding the major topics addressed in this work. Section 3 introduces the fundamentals regarding the research and development of proposed key metrics. Section 4 introduces the proposed key metrics, and a case study explains in a step-by-step approach the calculation process of proposed key metrics. Section 5 is a discussion regarding the results obtained in the previous section and the respective academic and managerial implications. Finally, Section 6 presents the major conclusions and suggests further steps toward the improvement of the present research.

2. Literature Review

According to several studies, projects keep failing at an impressive pace, though the number of organizations, institutes, and bodies of knowledge that provide project guidance has exponentially increased over the recent years [17–20]. Two of the most renowned organizations that monitor the evolution of how projects evolve throughout the years (the PMI and the Standish Group), in their public reports, show that the results are far from positive. In the PMI's Pulse of the Profession report that covers a period from 2011 to 2019, the number of projects that experienced any type of scope creep rose from 41% in 2011 up to 53% in 2019. Furthermore, the number of projects with failed project's budgets has remained relatively constant at 35% between 2011 and 2019 [21,22]. Moreover, according to the report of the Standish group for the period between 2017 and 2020, the number of projects that failed reached a total of 19%, while the number of projects that experienced any type of failure or challenge reached up to 50%.

Although there may be many reasons behind the number of both organizations that lead projects to fail or become challenged, research points out three major areas that need further research [23–25]. They are: (1) Processes—the different existing project management processes according to institution or organization and how they are understood by different people in managing projects, (2) principles—the way project management rules and best practices are understood by different people, organizations, cultures etc., and (3) people—how the way project stakeholders work together to execute project tasks and activities impacts project outcomes and outputs.

In this work, the people aspect is addressed. Several studies show that more than individual skills and expertise, the ability to work efficiently together within a group or organization is twice a predictor of success [1,6,13,23,26]. For this reason, it is critical to address the people aspect to quantitatively understand how the way that people work together in projects may or not be correlated with project outcomes. The way people work together (also known as dynamic interactions in the workplace [1]) are better captured through the application of graph-based centrality metrics as several studies show [1,6,11–14,23,26].

The formulation and application of graph-based theory to understand the myriad of interrelationships between dynamic entities is not new and spans agriculture, anthropology, project management, biology, economics, marketing, criminology, political, computer science, and organizational studies—just to name a few [27–29]. Table 1 shows some of the most notable developments of graph-based metrics across the recent years.

Table 1. Development of graph-based centrality metrics.

Year	Event	Description
1930–1953	Formulation of graph theory by Jewish-Hungarian mathematician Dénes König.	Publishing of the König's Book—*Theorie der endlichen und unendlichen Graphen*—in USA. König's ideas started to be developed by Haary and Norman, and since then, began to be applied to study Social Networks [27–32].
1940–1950	Development of three most important graph-based metrics: (1) In-degree, (2) out-degree, and (3) total degree.	Psychologists Leavitt, Bavelas, and Smith in 1950 developed three of the most popular centrality measures [1,4,8]. These are used to measure how many links or preferences one entity (person, group, or organization) receives or gives from or to other actors of the social network where they exist.
1950–1970	Development of Betweenness centrality.	Started to be developed in the late 1940's by Cohn and Marriott, was finalized in the late 1970's by Anthonisse (1971), Freeman (1977), and Pitts (1979) [9,33]. Betweenness Centrality calculates the shortest path between every pair of nodes in a connected graph, and it can be used to describe the amount of influence that an entity has over the flow of information in a network. It is also often used to find entities that serve as a bridge between two different blocks of a network [9,33].
1960–1975	Development of Closeness centrality.	Closeness centrality was developed followed the works of Bavelas in 1950, Harary in 1959, by Beauchamp in 1965, and Sabidussi in 1966, and finalized by Moxley and Moxley and Rogers in 1974. It measures how close one entity is to all the other entities within a network [9,33].
1970–1980	Development of Density.	Another popular centrality measure that are used to characterize group cohesion is the Density. Started by Bott in 1957 and finalized in 1980 by Thurman, it represents how strongly or how weakly a network is connected regarding the number of links between entities, which represents how far an entity can reach another entity through a set of intermediate links [9,33].
2000–2017	Redevelopment of the centrality concept in graph-based theory	The latest research argues that the centrality concept needs to be revised and should not be uniquely dependent on the position of an entity in a network as Sabidussi in 1966 and Freeman in 1979 proposed [33,34]. Such redevelopment stated that some centrality metrics in isolation may be inefficient to explain dynamic behavior. They argue that the nature of work that the entities execute should also be added when analyzing dynamic behaviors or that centrality metrics should be supported by some type of other metrics from other scientific areas [33,34].

As it can be seen in Table 1, the redevelopment of centrality metrics suggests that existing centrality metrics in isolation do not efficiently characterize measured dynamic behavior (informal relationships). There is a need to support existing graph-based centrality metrics in order to extract as much as possible insightful information when analyzing the interactions of entities within a network. This can be done with the modification of existing graph-based centrality metrics and with the development of new metrics.

However, research and development have been conducted in recent years not only on centrality measures. A very popular field called formation theory uses predictable models based on graph-based centrality and dispersion metrics to generate random networks, which produce graphs with small-world properties that mirror how certain actual parameters function, as well as how future relationships will evolve and emerge in the future [35,36]. Such models assume that network formation is based on a probability of attachment between any two entities called a preferential attachment mechanism, which is the basis of almost 80% of all relationships [35,36].

Applying graph-based centrality metrics in project management is still in a very initial phase, however, research shows that there are some considerable benefits of its application. For example, researchers argue that centrality in project management can be a measure of prestige, importance, influence, and control [1,34,35]. Centrality can still be used as a measure of coordination and collaboration performance in project management tasks and activities' execution, for example [37]. Research also shows that centrality plays a key role in project decision-making. For example, research shows that network position strength (known as centrality) and network tie strength (known as familiarity) have a positive effect on project decision-making [38].

In this work, we address the suggestion from [33,34] by adding other scientific areas to existing centrality metrics, namely statistics, developing new centrality metrics based on graph theory, and still reinforcing the application of centrality metrics in project management to measure individual and collective performance, as suggested by research, by analyzing five most voted relational dimensions that emerge and evolve among project management stakeholders.

3. Materials and Methods

In this section, we will introduce and develop the five key collaborative dimensions (5-KRD), the respective proposed metrics for each one of the five dimensions, and the necessary data to be collected (PEICs—project exchange information channels) for each one of the proposed metrics. The graph-based metrics proposed in this work comprise existing, adapted, and new metrics to analyze the 5-KRDs that emerge and evolve as people work together across different phases of a project lifecycle. These five key dimensions result from a survey conducted between 2018 and 2021 with 700 international project stakeholders from eight different business sectors, where participants, among other questions, were asked to name some of the most important dimensions of collaboration in project environments. From 700 surveyed project stakeholders, 558 valid answers were obtained, wherefrom the most voted project relational dimensions form the abovementioned 5-KRDs. These are: Construction sector with 48% valid answers, Food and Beverage with 24% valid answers, IT with 21% valid answers, Cosmetics with 12% valid answers, Life Sciences with 10% valid answers, Banking with 9% valid answers, Healthcare with 7% valid answers, and Car Industry with 4% valid answers. The five KRDs are: (1) Communication, which characterizes how different entities within a given project social network, communicate, and the respective insight as to what is being communicated, (2) internal and external collaboration, which characterizes how entities within and between organizations or departments exchange information needed to carry out activities or tasks to accomplish project related tasks and activities, (3) know-how exchange and power, which characterizes how know-how is being created and shared, and the informal power that is exerted between the entities of a group, or different groups, (4) clustering (variability effect), which characterizes how relationships are developed across a bounded and finite period of time, between entities of a group, or different groups regarding group cohesion degree, and finally (5) teamwork performance, which characterizes to what extent team effectiveness is related with efficient execution of project-related tasks and activities. Table 2 illustrates a detailed description of each one of the 5-KRDs that will be analyzed in this work.

Thought communication and collaboration can be considered high-level dimensions in projects (meaning that they may contain other sub-dimensions, such as information exchange, for example), in this work, the aim is to clearly isolate the most voted dimensions (sub-dimensions) associated with communication and collaboration. This is done in order to enable a deeper insight into how relationships emerge and evolve in organizations and the impacts on how work is performed in organizations. Therefore, we divided communication and collaboration into several dimensions (presented in the survey to project stakeholders).

Table 2. The five critical key collaboration types (5-KRD) detailed.

1- Communication	How do project roles, such as project managers, experts, engineers, or project administrative roles, communicate and the respective consequences of such communication behavioral patterns? Topics such as reach, strong or weak feedback, and the presence of project roles in project meetings are suitable to be analyzed.
2- Internal and external collaboration	How strong is the dependency level regarding project-related information between any two given project teams or groups? What level of collaboration (collaborative overload or lack of collaboration) is practiced in a project social network?
3- Know-how exchange and informal power	How is project-related information shared across the different project stakeholders of a project social network? How do influential informal and usually invisible project stakeholders influence decision-making and the execution of tasks and project activities?
4- Team-set variability	How does the variability of a project team-set impact project outcome? Does an unchangeable team set from the beginning until the end of a project help to achieve more project success than a continuously changing project team set?
5- Teamwork performance	How is the level of project team performance measured in feedback replies regarding important project information?

For each one of the 5-KRDs, centrality metrics are associated in order to enable the characterization of each one of the mentioned 5-KRD. For example, for the communication dimension, and because this dimension may involve many other sub-dimensions, three metrics have been developed. They are: (1) Role attendee degree, (2) internal mail cohesion degree, and (3) feedback degree. The data source for these three metrics are project meetings and project emails. For the Internal and external collaboration, the metric Information Seeking/Provide Degree was created. The data source for this metric is project emails. For the Know-how exchange and informal power dimension, the Action Key Players metric was created. The data source for this metric is project surveys (questionnaires). For the Team-set variability the Meetings Cohesion Degree metric was created, and the Teamwork performance metric was created. Detailed information regarding each one of the metrics is illustrated in the case study section. The data source for these metrics is project meetings. The necessary data to be collected in each one of the project information exchange channels (PEICs) are illustrated in Table 3.

Table 3. Project exchange information channels and respective required data.

PEIC	**Necessary Data for Proposed Metrics**
Project Meetings (Events)	Number of conducted project meetings in each one of the phases of a project lifecycle Number of participant project stakeholders in each one of the project meetings Project role name and to which team the respective project role belongs
Project Exchanged Mails	Number of exchanged emails sent/received in each one of the phases of a project lifecycle that regards project related information. Emails are organized as follows: - *Emails sent seeking help regarding project tasks and activities* - *Emails sent providing help regarding project tasks and activities*
Project Surveys (Questionnaires)	Conduct a simple social network analysis assessment by applying pre-defined questions that uncover important project-related information. Questions can be as follows: - *Question A: Whom do you turn to, to get information or help concerning project-related issues that is important to execute your project's activities and tasks?* - *Question B: Whom do you ask for permission/approval or advice regarding the starting of the execution of project tasks and activities, even if these have been already previously communicated?*

Regarding the application of the seven proposed metrics, a specific framework that guides the implementation and calculation process of each one of them throughout all the existing phases of a given project lifecycle is illustrated in Figure 1.

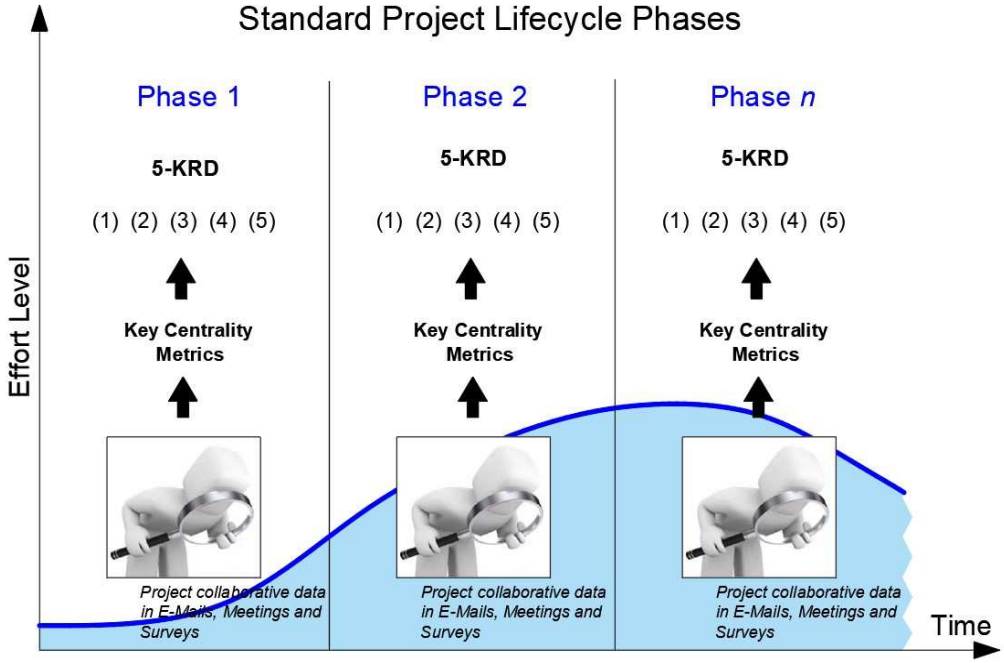

Figure 1. Data collection and analyzing process.

Figure 1 shows the data collection and analyzing process of the developed graph-based centrality metrics proposed in this work. There are essentially four steps. In step 1, the phases of a project lifecycle must be clearly identified. In step 2, necessary data according to Table 3 must be collected. In step 3, a set of graph-based centrality proposed metrics will be applied to the collected data. Finally, in step 4, the results of the application of the proposed metrics will be used to characterize each one of the 5-KCDs.

4. Development and Application of Proposed Metrics

4.1. Proposed 7 Graph-Based Centrality Metrics

Table 4 illustrates the seven metrics proposed in this work, the correspondent five key relational dimensions, the data source of each one of the metrics (PEIC—Project exchange information channels), and the main and auxiliary measurements, which correspond to the first and second measurement, respectively.

As an example, to characterize the internal and external collaboration relational dimension, only email project-related data regarding seeking and providing will be collected. Then, the collected data will be analyzed by the application of in- and out-degree (first measurement), and then by the application of basic statistics—the mode (second measurement). Finally, the results will be outputted and are ready for the interpretation steps, which may include the correlation of results with project outcomes and outputs.

4.2. Case Study

The seven proposed metrics in this work will be explained in detail, supported by a case study conducted in a life science organization in mid-Europe in 2021. In this work only, the part regarding the calculation process of the key metrics will be illustrated. A small organization (<80 workers) applied the proposed graph-based centrality metrics in an R&D project with a duration of six months, in order to uncover in a quantitatively way the myriad of relationships that emerged and evolved across the execution of the project. The project is named project P1 and concerns the development of a new endoscopy equipment part to be assembled in the final endoscopy equipment. Figure 2 illustrates the full project lifecycle as well as the participating stakeholders.

Table 4. The seven graph-based metrics proposed in this work.

Sources Metrics	PEICs			First Measurement	Second Measurement	5-KRD (Five Global Collaboration Types)
	Data from Meetings	Data from Mails	Data from Questionnaires			
Metric M1-Role attendee degree	x			SNA: Total In-degree	Statistics: Linear Regression	Communication
Metric M2-Internal mail cohesion degree		x		SNA: Total degree and Density	Statistics: Average	
Metric M3-Feedback degree		x		SNA: In-degree and Out-degree and Reciprocity	Statistics: Mode	
Metric M4-Information Seeking/Provide degree		x		SNA: In-degree and Out-degree	Statistics: Mode	Internal and external collaboration
Metric M5-Action key players			x	SNA: Total In-degree	Statistics: Mode	Know-how exchange and informal power
Metric M6-Meeting's cohesion degree	x			SNA: Average weighted total-degree	Statistics: Linear Regression	Team set variability
Metric M7-Teamwork performance	x			SNA: Total In-degree	Statistics: Average	Teamwork performance

x = means that for a given PEIC (meetings, mails, or questionnaires), a given metric M (1, 2, 3, . . . , 7) is used.

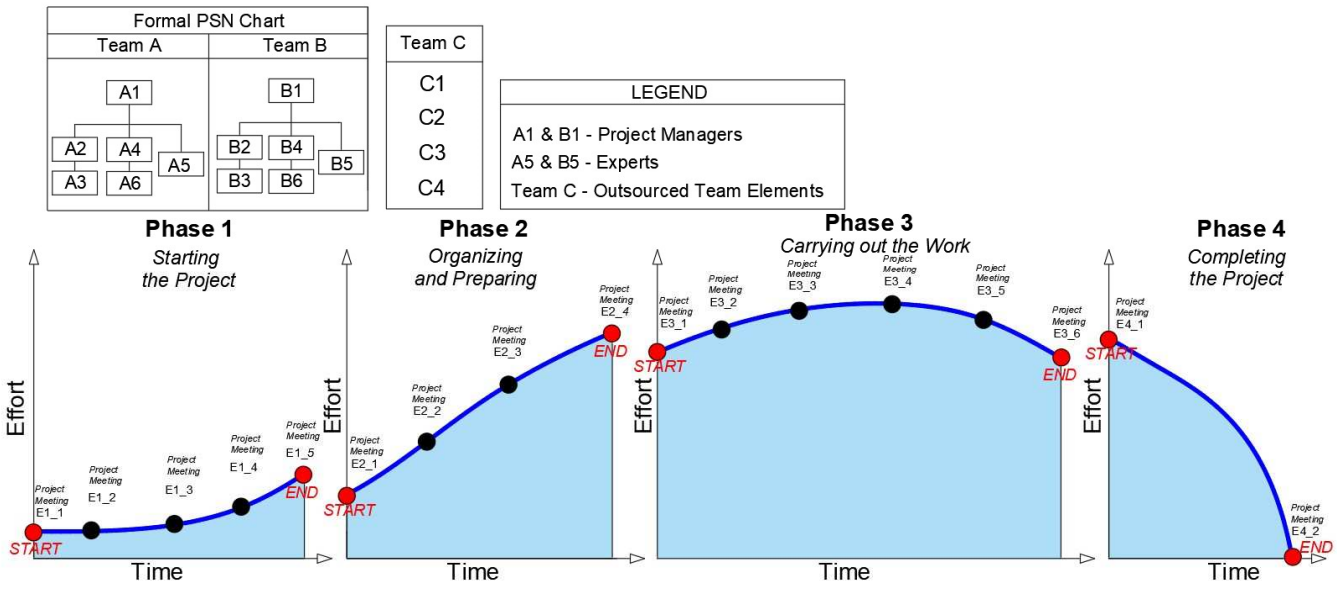

Figure 2. Project lifecycle phases of Project P1.

The project to be analyzed is project P1 (Figure 2) and it was delivered by two project teams (team A and team B) of the life sciences organization that collaborated across the P1's four project phases.

In this work only, a reduced part of the information captured in the whole assessment will be illustrated due to restrictions. However, the calculation process is affected by this reduction.

The Official Project Roles designated to accomplish the project P1 are displayed in the upper left corner of Figure 2 (Formal PSN Chart) and disclosed in the legend above the project lifecycle of P1.

The project roles include project managers, experts, and outsourced team members. All the nondisclosed official project roles in this case are to be considered All, according to

Table 5. There are six official project people from both teams that are planned to accomplish project P1.

Table 5. Independent and collective analysis of the Project Official Roles of Project P1.

Metrics Number	Independent PSN Stakeholders			Global PSN Stakeholders
	Project Managers	**Experts**	**Outsourcers**	**All Official Defined Project Roles (Team A and Team B)**
Metric M-1	**x**	**x**		
Metric M-2	**x**	**x**		**x**
Metric M-3				**x**
Metric M-4				**x**
Metric M-5			**x**	**x**
Metric M-6				**x**
Metric M-7				**x**

x = means that for a given Independent/Global PSN Stakeholder, a given metric M (1, 2, 3, . . . , 7) is used.

In project P1, in phase 3, a third party—outsourced Team C—participated in some project activities. The elements (c1, c2, c3, and c4) of Team C are identified in Figure 2 (Team C). In this phase, the data collection process took place according to Table 3. In each project phase, a set of project meetings (Events E) took place, which is illustrated in Figure 2. At the end of each one of the project phases of project P1, all the project-related email data exchanged are collected according to Table 3. Across this work, only data from phase 1, phase 2, and phase 3 of project P1 will be used for the demonstration of the calculation process of the seven proposed metrics.

Four different official project roles (OPR) will be considered. They are Project Managers, Experts, Outsourcers, and All (all other administrative project roles that take place in the execution of the project P1). The OPR will be analyzed independently and collectively (Table 5). Independently means that some official project roles will be analyzed separately across the different P1's project phases. Collectively means that either all, or combination of certain official project roles, will be analyzed throughout all the different phases of a project lifecycle.

For example, for the metric Internal mail Cohesion (M-2) degree displayed in Table 5, there are two types of analysis. The first one is an independent analysis of the project managers and the experts in an isolated mode. The second is a global analysis (collectively) of all the project stakeholders (also known as project people) that participated in a project, which includes all the officially defined project roles.

4.2.1. Role Attendee Degree

Description: This metric captures the presence of two important stakeholders (Project Managers and subject matter Experts) in project meetings throughout a given project phase across P1's project lifecycle. It calculates a trend line (across a phase of a project), positive, negative, or constant, regarding the participating rate of the desired OPR. In this work, project managers and experts from both teams will be analyzed.

Method: The presence of the OPR across a project phase will be recorded and plotted in a cartesian graph (Figure 3b), where the attendance in one project meeting will be given a value of 1, and non-attendance will be given a value of 0. After that, a linear regression will be calculated (trend line), and the evolution signal will be calculated. There are four possible outcomes (Figure 4). They are: (1) Increasing (positive evolution across a given project phase), (2) Decreasing (negative evolution across a given project phase), (3) Full (constant evolution across a project phase, where the chosen OPR participated in all project meetings across a project phase) and (4) Neutral (constant evolution across a project phase, the chosen OPR did not participate in all project meetings across a project phase).

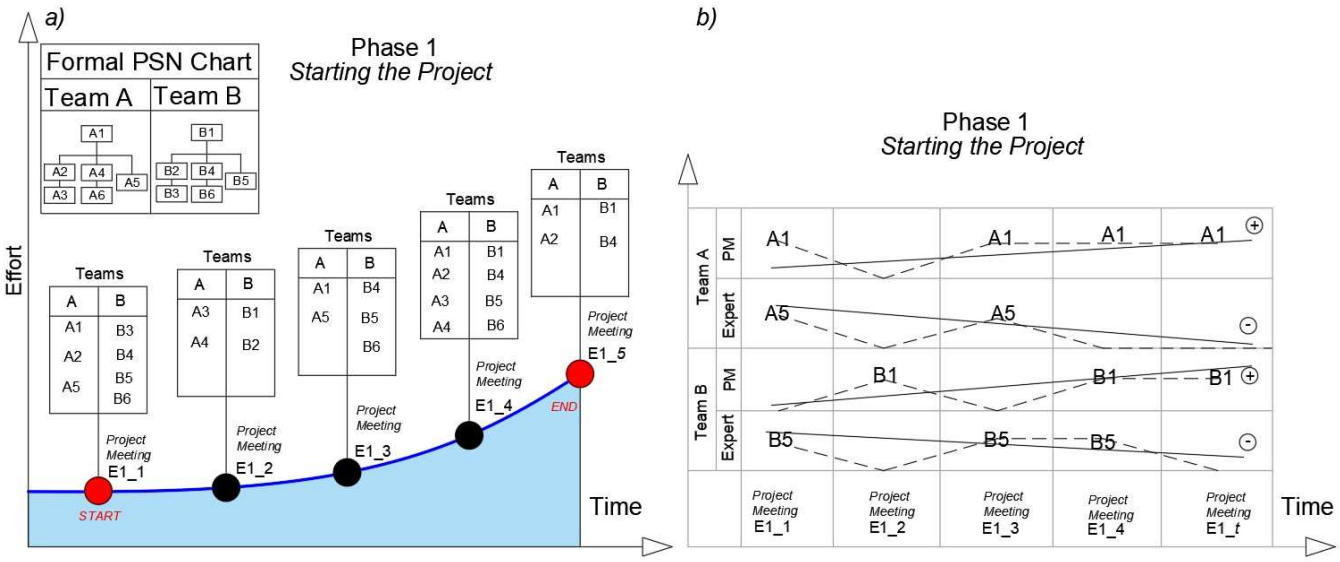

Figure 3. Role Attendee Degree Calculation for Project P1. (**a**) PLC of phase 1 and respective project meetings; (**b**) Evolution across Phase 1 regarding PMs and Experts from teams A and B.

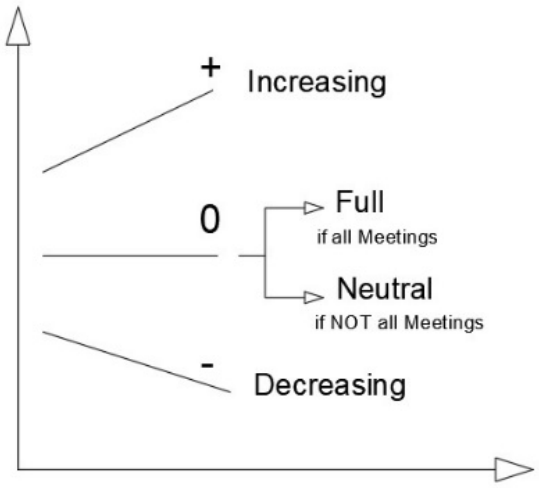

Figure 4. Role Attendee Degree Evolution Outputs.

Uncovers: What type of evolution (increasing, decreasing, full, or neutral) based on the Role attendee degree in project meetings within a project phase, exists with higher frequency.

Figure 3a illustrates phase 1 of project P1.

In this phase, there were five project meetings (E1_1 up to E1_5) where project participants of two teams worked together from the beginning until the end of phase 1. From Team A, project element A1 is the project manager and element A5 is the expert. In this case, there is only one expert in each of the Teams A and B. However, multiple roles, as for the expert's case, are supported by the proposed metrics. The other elements are Engineers from different areas, such as Processing, Designing, Automation, etc. In Team B, project element B1 is the project manager and B5 is the expert. The same goes for the remaining elements of Team A. Figure 3b presents how the metric Role Attendee Degree is calculated. As an example, project element A1 participated in four out of five meetings that took place in phase 1 of project P1. A1 participated in the E1_1 (value = 1), E1_3 (value = 1), E1_4 (value = 1), and the E1_5 (value = 1) meeting. Project element A1 did not participate only in the E1_2 (value = 0) meeting. This evolution is seen in Figure 3b, as the black line indicates the real evolution regarding element A1, and the blue line is the resulting evolution of time outputted by applying linear regression across the meetings that element A1 participated

and did not participate. The resultant evolution is positive (+). This means that element A1 had higher constant participation in project meetings in phase 1, as phase 1 was nearing its end. The same applies to the other three OPRs—A5, B1, and B5.

As mentioned, there are four possible outcome types for this metric (Figure 4). They are: Increasing (positive evolution), Decreasing (negative evolution), Constant Full (participation in all project meetings), and Neutral Constant (participation in some project meetings).

In the case of project P1 (Figure 3), the project manager of Team A (A1) had a positive evolution (+), whereas the expert of Team A (A5) had a negative evolution (−) across phase 1. For Team B, the project manager B1 had a positive evolution (+), and the expert B5 had a negative evolution (−) across phase 1 of project P1.

4.2.2. Internal Mail Cohesion Degree

Description: In the first approach, this metric captures the percentage of project people from both Teams A and B, that were involved in all email communication that concerns project-related information across a project phase of a project lifecycle. For this metric, all mails that were sent/received directly to, forwarded to, or in CC to, will be used as input for the metric. As an example of application, (first approach) this metric aims to calculate the email communication cohesion degree, within the project Team A. In the second approach, it will analyze the Total Degree (in-degree + out-degree) of the two already named OPR (Project Managers and Experts).

Method: In the first approach, the density of the email communication network will be calculated. All emails that contain project matter information related sent and received by elements of Team A, will be collected and analyzed. A graph will be created to illustrate the mail communication, and the density metric will be calculated according to (1) (adapted from [9]).

$$d = \frac{2LM}{NM(NM-1)} \quad (1)$$

where:

LM = total number of existing links at the email communication network
NM = total number of project people connected, within the email communication network

Uncovers: To what extent does not being in all email communication network that relates project information across a given project phase that officially (according to formal chart) belongs to a project influence project outcome?

Figure 5 represents phase 1 of project P1. In the upper right corner, the graph inside the box that contains Team A and Team B represents the email communication network that contains all the exchanged project-related emails across phase 1 of project P1. For the first approach, the cross-boarded (from Team A to Team B, and within Team B) emails exchanged will not be analyzed. For example, it is visible that there is not a link between A1 and A2. This means that across phase 1 of project P1, there was no single email directly exchanged between A1 and A2 concerning project-related matter. The same happens, for example, between elements A6 and A1.

This shows, according to the email communication network, that there has been information that might have not been fully shared with all the elements of project Team A. If there was a link between all elements of Team A, this could mean that all information had been shared with all the project people of Team A. This does not necessarily mean, however, that all information has not been shared across all the elements of Team A. For example, the information that flowed in the links between A1 and A3, A1 and A5, and A1 and B1, might have been forwarded by A3, to A2, A5, and A4. However, that might, or might not have taken place, and if yes, it still might have occurred with a certain time delay. In this case, the proposed metric, due to privacy and legal constraints, does not enable further disclosure.

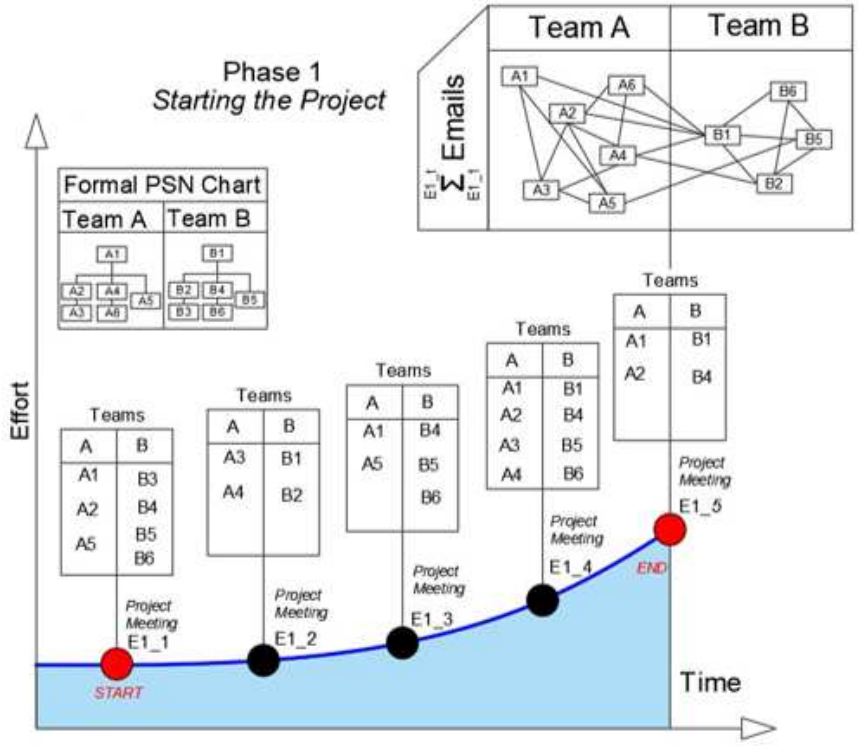

Figure 5. Internal mail cohesion degree calculation for Project 1.

First Approach

To measure the email communication network cohesion degree, the density (1) will be used. The maximum value for the density is when all elements of Team A have a link between them. Applying (1):

$$d = \frac{2 \times 9}{6(6-1)} = 60\%$$

These results show that through the mail communication network, 60% of all possible connections (100%) are present in phase 1.

Second Approach

In the second approach, the total degree (2) will be measured for two OPR—project managers and experts. This is illustrated in Table 6. The total degree, which represents all the links (incoming, and outgoing) that one project person has, is given by (3) (adapted from [9]).

$$\boldsymbol{T_D}(NM_i) = \sum NM\_l_i \quad (2)$$

where:

$\boldsymbol{T_D}$ = *total degree in the email communication network*
NM = total number of project people connected within the email communication network
i = project person = 1, 2, 3, . . . , *NM*
NM_l_i = *total number of existing links attached to project person i*

Table 6. Total Degree for Project Managers and Experts.

	Team A		**Team B**	
	Project Manager (A1)	**Expert (A5)**	**Project Manager (B1)**	**Expert (B5)**
Total Degree	3	4	7	4

In Figure 5, element A1 has three links and the A5 has four links. In Team B, B1 has seven links and B5 has four links. In this case, it is clear that Team B has an advantage regarding the Project Manager total-degree, and there is an odd regarding experts of both teams. It means that that the project manager from Team B holds an advantage regarding the centrality in the email communication network, making him probably a more powerful stakeholder than the project manager from Team A, regarding the email communication network. Regarding the experts, none of them holds an advantage regarding this metric. Now, to better understand the purpose of this metric, assuming Team A as a service provider and Team B as a customer, and the email communication network as the relationship between them, it could be concluded that the project manager from the customer side holds a privileged position regarding the email communication network. The next step would be the analysis to what extent such relationship is correlated with project failure or project success.

4.2.3. Feedback Degree

Description: This metric uncovers the percentage of all project-related emails that were sent between the teams, in this case, from Team A to Team B. It does not show exactly if one particular mail has been replied to (based on its content), rather the overall number of exchanged emails. This metric aims to uncover from which side (Team A or Team B) the email communication network is more intense, which could reflect more or less control over the email network, and ultimately more or less feedback.

Method: For this purpose, the reciprocity metric will be used, which is simply the ratio between the emails sent from one team to another team.

Uncovers: To what extent does a high or a low project-related information email exchange from a given project team is correlated to a project outcome (usually success and/or failure)?

Figure 6 presents the mail communication from phase 2 of project P1 between Team A and Team B. To calculate the feedback degree, the emails sent/received from/to need to be identified. For this case, the in-degree (representing an email received) and the out-degree (representing an email sent) need to be first calculated. The in-degree, which are all the links that one project person receives, is given by (3) adapted from [9]).

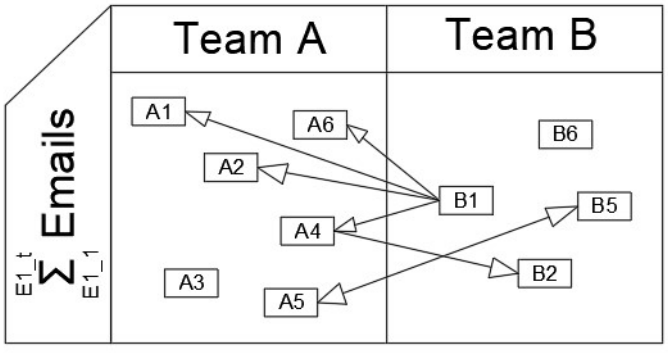

Figure 6. Feedback Degree Calculation for Project P1.

$$\boldsymbol{I_D}(NM_i) = \sum NM_{lin} \tag{3}$$

where:

$\boldsymbol{I_D}$ = *In-degree in the email communication network*
NM = total number of project people connected, within the email communication network
i = project person = 1, 2, 3, . . . , *NM*
NM_l_{in} = *total number of existing in-links attached to project person i*

Applying (4) to elements of Team A, and Team B respectively:

$\boldsymbol{I_D}(A1) = 1$
$\boldsymbol{I_D}(A2) = 1$ $\quad$ $\boldsymbol{I_D}(B1) = 0$
$\boldsymbol{I_D}(A3) = 0$ $\quad$ $\boldsymbol{I_D}(B2) = 1$
$\boldsymbol{I_D}(A4) = 1$ $\quad$ $\boldsymbol{I_D}(B5) = 1$
$\boldsymbol{I_D}(A5) = 1$ $\quad$ $\boldsymbol{I_D}(B6) = 0$
$\boldsymbol{I_D}(A6) = 1$

The out-degree, which are all the emails that one project person sends to other, is calculated applying by (4) adapted from [9].

$$\boldsymbol{O_D}(NM_i) = \sum NM_{lout} \tag{4}$$

where:

$\boldsymbol{O_D}$ = *Out-degree in email communication network*
NM = total number of project people connected, within the email communication network
i = project person = 1, 2, 3, . . . , *NM*
*NM_*l_{out} *= total number of existing out-links attached to project person i*

Applying (5) to elements of Team A and Team B, respectively:

$\boldsymbol{O_D}(A1) = 0$
$\boldsymbol{O_D}(A2) = 0$ $\quad$ $\boldsymbol{O_D}(B1) = 4$
$\boldsymbol{O_D}(A3) = 0$ $\quad$ $\boldsymbol{O_D}(B2) = 0$
$\boldsymbol{O_D}(A4) = 1$ $\quad$ $\boldsymbol{O_D}(B5) = 1$
$\boldsymbol{O_D}(A5) = 1$ $\quad$ $\boldsymbol{O_D}(B6) = 0$
$\boldsymbol{O_D}(A6) = 0$

As a conclusion, Team A sent two mails to Team B, and Team B sent five mails to Team A. Total mails sent between Teams were seven. The feedback degree will be calculated by applying the reciprocity given by (5) adapted from [9].

$$RM = \frac{Sent\ Mails\ low}{Sent\ Mails\ high} \tag{5}$$

where:

RM = Reciprocity in email communication network
Sent Mails low = sum of the lowest number of emails sent by one given team
Sent Mails high = sum the highest number of emails sent by one given team

Applying (6):

$$RM = \frac{2}{5} = 40\%$$

There is a 40% reciprocity in the mail communication network between Team A and B, in phase 2 of project P1. This means that only about 40% of all emails send between Team A and B during phase 2 of project P1 were replied to. In this case, three emails have not been replied to and the Team B has the highest number of emails sent and emails non-replied.

4.2.4. Information Seeking/Providing Degree

Description: This metric uncovers which team (Team A, or Team B) is more or less dependent on project-related information. Only the emails that contain project-related information will be analyzed. This specific type of information has to be related with seeking and providing help regarding project related activities.

Method: For this purpose, all mail communication will be assessed and filtered according to seeking and providing help regarding project-related matters. This means that the email content will have to be disclosed. Access to the email content requires the permission of the organization and the respective employees. If permission is not given then this metric is limited to analyzing the email subject, being conditioned to an individual follow-up analysis regarding the respective involved employees. Next, the ratio between mails seeking help and emails sent by those providing help will be calculated.

Uncovers: Which team is more information-dependent to execute project-related activities? To what extent is the dependency of a certain team correlated to a given project outcome (usually failure and/or success)?

The upper right corner of Figure 7 shows the email communication network between Team A and B regarding mails sent seeking for help and mails sent providing advice or help regarding necessary project information to accomplish project activities across phase 1 of project P1. Mails sent asking for help are identified with blue color. Mails providing information are identified with green color. The results regarding emails sent/received are presented in Tables 7 and 8. In this case, in-degree and out-degree metrics will be applied according to (3) and (4) to Teams A and B.

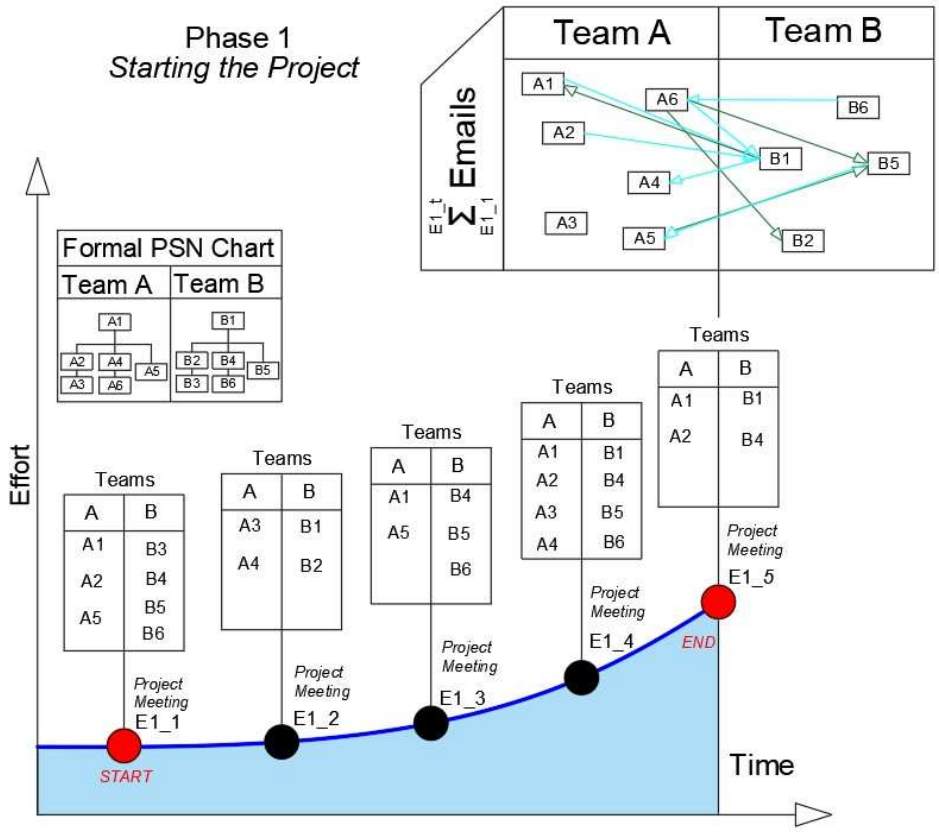

Figure 7. Information Seeking/Providing degree calculation for Project P1.

Table 7. Mails sent seeking help.

Blue Color	**Team A**	**Team B**
Team A	-	3
Team B	3	-

Table 8. Mails sent providing help.

Green Color	**Team A**	**Team B**
Team A	-	3
Team B	1	-

Team A sent three mails looking for help and only received one mail providing help from Team B. Team B sent three mails asking for help and Team A sent back three mails providing help. It can be concluded that both teams have the same dependency degree

(seeking), but different providing help levels or degrees. The seeking and providing reciprocity can be calculated applying (6) for both seeking and providing as follows:

$$Seeking\ R = \frac{3}{3} = 100\%$$

$$Providing\ R = \frac{1}{3} = 33\%$$

This concludes that both teams, A and B, are equally information-dependent, but Team A has a disadvantage because not all information requests were satisfied through the email communication network, which makes Team A more information-dependent than Team B. There are two possible outcomes for this metric. Either both teams are equally dependent, and in that case, the seeking and providing reciprocity degrees are 100%, or one of the teams is more or less dependent, as for example, in the case of Figure 7. Results that are equally dependent are considered neutral and, therefore, no conclusion can be outdrawn.

4.2.5. Action Key Players

Description: This metric is to be applied, but not only when a third party is outsourced by one of the teams, A or B, to execute project activities in a given project phase. This metric uncovers what are the key players among the elements Teams A and B that share know-how and provide guidance to the third team in order to execute project activities. In other words, it aims to identify who has the power to delegate and take decisions, and to what extent the way these decisions are taken influences project outcome.

Method: A simple graph analysis (also known as social network analysis) will be conducted addressing all elements of the third team (usually called Team C, or TC) in order to find out who the most important people are (informally) for Team TC regarding support (know-how and decision-making) so that Team TC can execute project activities which it was outsourced for. Two questions will to be asked to the Team TC in the assessment. These questions are also illustrated in Table 3. After the SNA assessment is ready, by applying SNA theory, key players will be identified. They will be essentially identified by using in-degree and out-degree, to find Central Connectors and Peripherical people within Teams A and B.

Uncovers: To what extent does the know-how transfer and decision-making power, coming either from Team A or from Team B influence a project outcome in project phases where a third team is needed/outsourced to execute project-related activities?

Figure 8 presents phase 3 of project P1. In this phase (carrying out the work), a third team (Team C) was outsourced to execute project-related activities. Social network analysis with the two strategic questions was conducted, addressing the elements of the outsourced team (c1, c2, c3, c4), and the results are displayed in the upper right corner box in Figure 8. In this case, blue lines are answers provided by Team A, and green lines are answers provided by Team B. The quantitative results for both questions are to be illustrated in Table 9 by applying (3).

According to the results in Table 9, it can be concluded that Team A has a privileged position regarding providing help, sharing know-how to execute project-related tasks. However, Team B takes control of the decision-making process when it comes to deciding what is to be done. For this metric, three different possible results for each question are possible. They are illustrated in Figure 9.

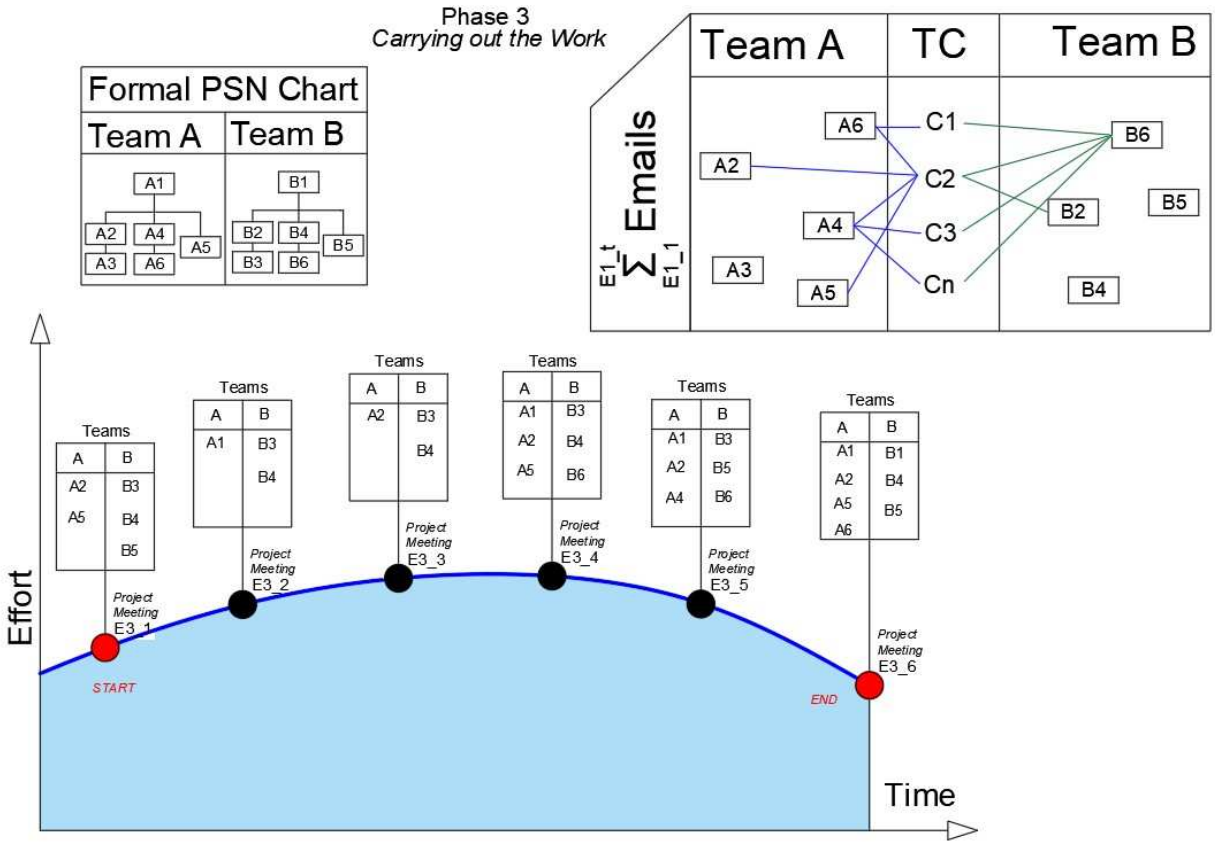

Figure 8. Action Key Players Calculation for Project P1.

Table 9. SNA Questionnaire results (In-degree) for Project P1.

Question 1 (In-Degree)		Question 2 (In-Degree)	
A2	1	A2	0
A3	0	A3	0
A4	3	A4	0
A5	1	A5	0
A6	0	A6	0
B2	1	B2	0
B4	0	B4	0
B5	0	B5	0
B6	0	B6	4

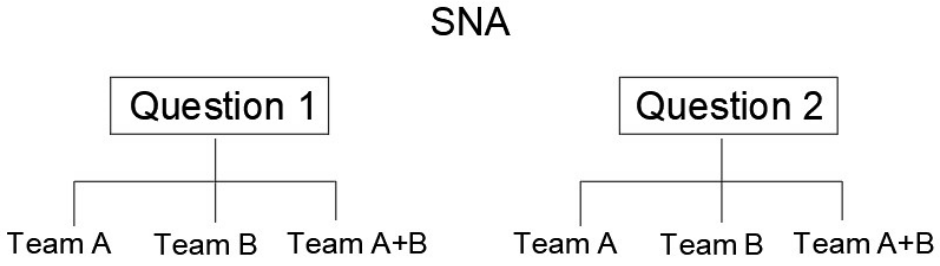

Figure 9. Possible outcomes for metric Action Key Players after applying a simple SNA.

4.2.6. Meetings Cohesion Degree

Description: This metric was developed to quantitatively capture the complex project people variability (PSNVar—Project Social Network Variability—Figure 10) regarding the participation in F2F project meetings across a phase of a project lifecycle in a simplified and meaningful way, so that it could be translated into a single value that enables to correlate it with a project outcome. It can also be used in other project meeting environments apart from the F2F. The variability is the function of the project people that start at the very first project meeting of each project phase—they usually are at the formal chart—characterized as people that are designated to accomplish a project—phase. It includes the project people that start, leave, restart, project meetings across a project phase. This metric measures the project network social cohesion degree variation regarding meeting participation of project people across a project lifecycle based on the relationships that dynamically evolve across the project meetings of a project phase. In other words, if the same project people (project people that are officially designated to accomplish a project phase), participate in all the project meetings that occur in a given phase of a project lifecycle, a certain relationship type (project social cohesion) between them starts to emerge and keeps growing until the end of a project phase. This relationship can be translated into friendship, or simply awareness (who knows who), trust, or other, and may or may not affect a project outcome.

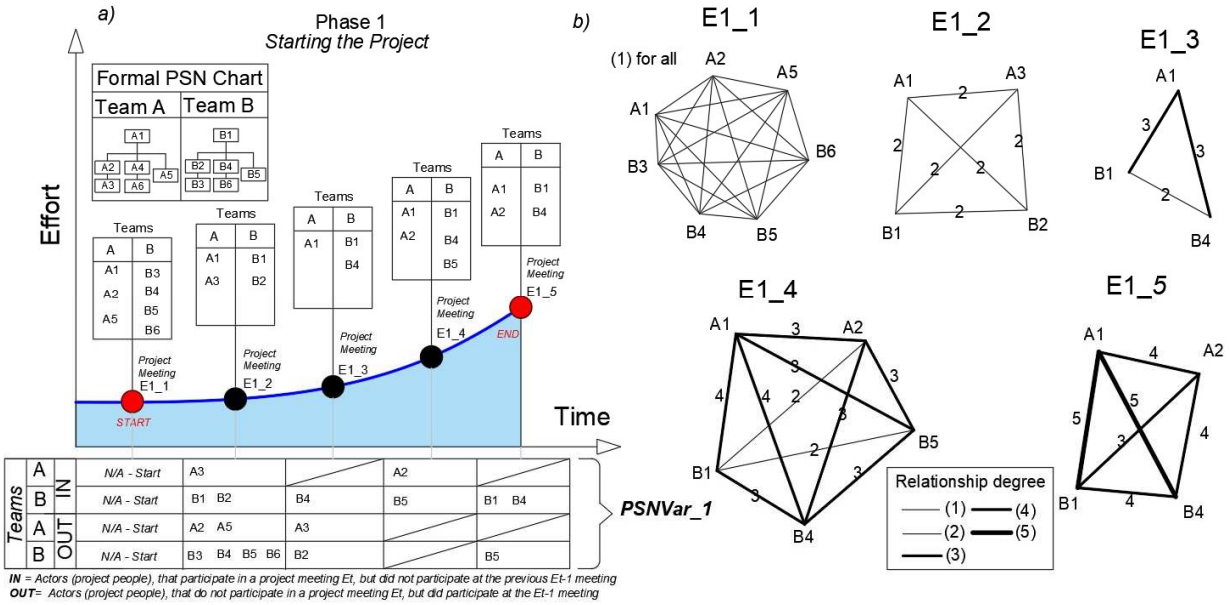

Figure 10. Meetings Cohesion degree calculation for project P1. (**a**) PLC of phase 1 and respective project meetings; (**b**) Different network arrangements based on participation degree in project meetings illustrated in (**a**).

Method: For this purpose, a metric was developed based on graph theory centrality metrics average in-degree. After the calculation of the variability for each project meeting, a linear regression (auxiliary measure) will be applied to find out which evolution of that line (positive, negative, or constant).

Uncovers: How does the variability (change of project people set) of project people that participate in project meetings in a project phase influence a certain project outcome? Does having an unchangeable project team set (the same elements of a project Team from the beginning until the end of a project phase), across a phase of a project lifecycle, regarding meetings participation, influence a project outcome?

Figure 10a shows project phase 1 of project P1. In this phase, there were five project meetings. In the first meeting, Team A elements (A1, A2, A5) and Team B elements (B3, B4, B5, B6) were present (this can be seen in the boxes above the dots that represent the different project meetings in Figure 10a). This means that for this metric, all these elements

met each other personally in the project P1 phase 1 context, for the very first-time regarding phase 1 of project P1. To be noted, the personal relationships or past relationships between project elements are not taken into consideration in this metric. Thus, all the project people that participated in meeting E1_1 have developed a link (relationship) with each other.

As an example, in Figure 10 b E1_1 A1 has a link to B6, which means that they were together in the first meeting of project P1 at phase 1. The first meeting is represented in a network in Figure 10b in the middle right corner as E1_1. In the first meeting, all the participants get a link from all the other participants (Figure 10b E1_1). This means that, for example, A1 has a link to all the others (A2, A5, B3, B4, B5, B6) of value 1. The value one (1) represents that they meet each other for the first time in a project meeting environment. Therefore, for A1, as for all other participants, the total in-degree at the first meeting will be 6 (all the links directed to A1). In the second meeting (Figure 10b E1_2), new elements are in and some elements that participated at meeting 1 are not there anymore. The only element that is in both meetings is A1. This means that A1 participated for the first time in a project meeting with all the other three (A3, B1, B2). Thus, A1 gets a link of value 1 from each of the others, which makes a total sum of three.

In the third meeting (Figure 10b E1_3), A1 reencounters B1 and B4. A1 and B1 were already together in the first meeting, thus now the link between them is of value two, which represents the second time that they are together in a project meeting. The same happens with A1 and B4. On the other hand, B1 and B4 meet each other for the first time in the third meeting. Therefore, the link between them is of value 1. The same principle is applied to all other project meetings (Figure 10b E1_4 and E1_5).

Figure 10a, under the project curve (blue line), shows a matrix which contains the project people variability regarding project meeting participation degree. Considering meeting E1_3 as the present meeting, elements A1, B1, and B4 participated in the respective project meetings. Element B4 is in the matrix categorized as IN. This means that element B4 did not participate in previous project meetings. Element A3, for example, on the other side is categorized as OUT. This means that he participated in the previous meeting but is not taking part in the present project meeting. The metric (6) developed to measure this variability measures exactly the number of times the same project people were together across the project meetings of a project phase. If the same people were always together in all the project meetings, the metric will output a constant value across time. If a change in the set takes place, the metric will immediately react and output a non-constant value for each project meeting.

$$V_{(Et)} = \frac{WL_{(Et)}}{TPP_{(Et)} \times Et} \tag{6}$$

where:

V = Variability of a PSN (project social network)
Et = Meeting (event) number, where Et = 1, 2, . . . , TE
TE = Number of project meetings (events) that occurred in a given project phase TPP = Number of project person that participated in an event Et.
WL = Value of all weighed connections (links), from each project stakeholder total degree in each project meeting (event) Et.

Applying (7), to all the meetings (Events):

$$V_{E1}(Teams\ A,\ B) = \frac{6+6+6+6+6+6+6}{7 \times 1} = 6$$
$$V_{E2}(Teams\ A,\ B) = \frac{3+3+3+3}{4 \times 2} = 1.5$$
$$V_{E3}(Teams\ A,\ B) = \frac{4+3+3}{3 \times 3} = 1.11$$
$$V_{E4}(Teams\ A,\ B) = \frac{10+7+7+9+7}{5 \times 4} = 2$$
$$V_{E5}(Teams\ A,\ B) = \frac{11+8+10+9}{4 \times 5} = 1.9$$

This metric outputs three different possible results (evolutions across time). They are: (1) Non-constant evolution positive (+), (2) non-constant evolution negative (−), and (3) constant evolution (0). Non-constant positive (+): Change in the project team set (possible increasing of new project elements). Non-constant negative (−): Change in the project teams set (possible decreasing of project elements). Constant evolution (0): No change in the project teams set (constant across all project meetings). For the example illustrated in Figure 10a, the respective evolution is represented in Figure 11. It shows that a negative evolution has occurred, which means that the resulting project team (Team A and Team B) has not been the same set from the beginning of that phase until its end. Furthermore, this evolution indicates that the participant numbers have been generally decreasing across the project meetings of that project phase in project P1.

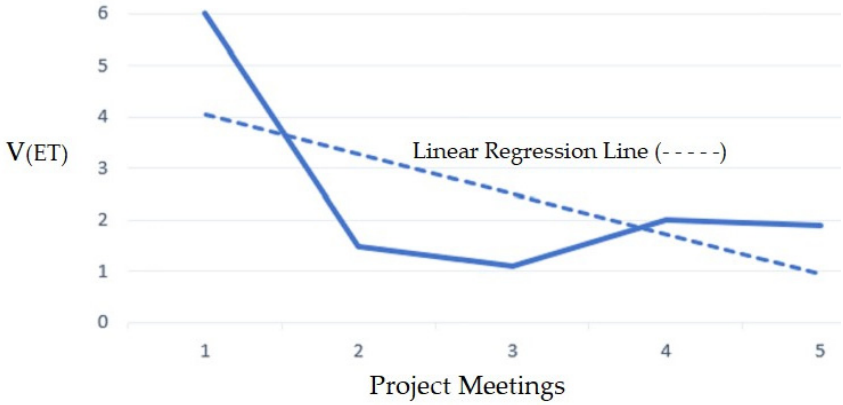

Figure 11. Linear regression evolution for Meetings Cohesion degree calculation for project P1.

4.2.7. Teamwork Performance

Description: This metric analyzes project-related information transferring speed (Average Feedback Speed when providing an answer to a project-related information question), of all Official Project Roles in all project-related email exchanges. This aspect in project management was named as a very critical one, being in fact the one that most respondents connected with efficiency within a given PSN, therefore, it is named teamwork performance.

Method: Average value of all feedback times of replied to emails within a project phase. This metric outputs an average hours-value that spans from 100% (which stands for an instantaneous reply that was made in less than 1 h) to 0% (stands for no feedback found across the duration of a project phase).

Uncovers: Feedback speed when proving an answer to a project-related question.

Figure 12a illustrates the email communication network between team A and team B only in phase 1 of project P1, and the respective duration in hours (Figure 12b). Only emails sent between different teams are illustrated in the links between the different project people in Figure 12a. The number of emails sent and received regarding a certain project-related subject is marked in yellow. For example, in phase 1 of project P1, project people A1 exchanged two emails with project people B1. This means that A1 asked B1 two times for project related information, and B1 replied to A1 two times. For this case, if an email has not been replied to within 480 h, it gets a value of 0, which means that no reply was made within the email network communication. If an email has been replied to in less than 1 h, it has a value of 100% (1). For each email interaction presented in Figure 12a, the resulting feedback time is illustrated in Table 10. For example, the two mails that A1 sent to B1 (this can be seen in Figure 12a in the yellow box line from A1 to B1) asking for project-related information (Figure 12a), both had a feedback time of 1 (100%). This means, that B1 replied to both emails from A1 in less than 1-h time period. In another example, the feedback first email time (0.3) between A2 and B1 is of 0.3 h, which means that it took 336 h to reply, on average. Two types of answers are defined. They are: (1) Instantaneous answer (1, or 100%):

Email has been replied to in less than 1-h period time, and (2) Infinite answer (0): Email has not been replied to within a project phase period time. In Figure 12b is illustrated the full duration in hours of phase 1 of P1.

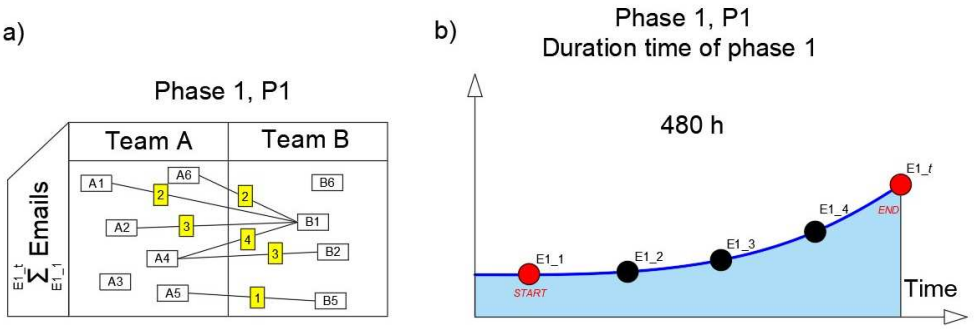

Figure 12. Teamwork performance Calculation for project P1. (**a**) Exchanged emails between elements of team's A and B in phase 1; (**b**) Duration time of phase 1 in hours.

Table 10. Interaction time Feedback.

			B1			**B2**		**B5**
A1	1	1	------	------	------	------	------	------
A2	0.3	0.4	0.8	------	------	------	------	------
A4	0.1	1	0.3	1	0.3	1	0.8	------
A5	------	------	------	------	------	------	------	0.1
A6	0.2	0.8	------	------	------	------	------	------

To calculate the transfer average speed, the following formula is to be applied (7):

$$Ts = \frac{\sum t_{a-b}}{TCMs} \quad (7)$$

where:

$\sum t_{a-b}$ = *Sum of all times from all replied to emails within a project phase.*
TCMs = Total of emails sent and replied within the email network communication

Applying (9) to Figure 12a:

$$Ts = \frac{1+1+0.3+0.4+0.8+0.1+1+0.3+1+0.3+1+0.8+0.1+0.2+0.8}{15} = 0.61$$

This means that, on average, all the emails that have been replied to within the email communication network between the two different teams had an average of 187 h, respecting phase 1 of P1.

5. Discussion

Across the previous section, the calculation process of the seven proposed metrics was illustrated in detail with the support of a case study. As it can be seen, the metrics efficiently capture in a quantitative way dynamic behaviors that emerge and evolve as a project moves to the end. The calculation process is simple and intuitive, nevertheless, it provides unique information regarding the hidden behavioral patterns that exist in every organization out there. The examples given across the case study are of low complexity in terms of calculation, however, they serve the purpose of illustrating the calculation process in a step-by-step approach. Nevertheless, due to GDPR restrictions, some metrics cannot go further in uncovering critical information to characterize a given key collaborative dimension. For example, in the internal mail cohesion degree metric, it is not possible to clearly analyze the content of email exchanged information to access what information

did flow between any two entities or groups, for example. This fact represents a certain drawback regarding the output of this metric. Nevertheless, if permission is given to access the content of exchanged information, then this issue is no longer a problem.

Regarding the role of attendee degree, the action key players, and the teamwork performance metrics, this issue is not a problem because there is no need to access restricted information. For example, the role attendee degree does not capture sensitive information that flows across elements of a given project social network, rather checks only the presence of key project stakeholders in project meetings. In the action of key players, this issue is also not a problem. However, another problem may arise, which has to do with the veracity of data provided in the questionnaire addressed to a third-party team. More concretely, the network analysis must consider the existence of bias in the answers of the participants, which may lead to misleading results and conclusions.

The application of the proposed metrics in projects that were successfully and unsuccessfully delivered may shed light on which critical success and failure factors are responsible for leading projects to a certain outcome. This can be uncovered if organizations have the necessary data and a substantial number of similar projects (the same project phases, the same industry, etc.) to be analyzed.

In a managerial dimension, the application of these metrics represents a new approach to tackling collaborative issues that may emerge and evolve across the different phases of a project lifecycle. In fact, several studies show that if the mix of informal networks is not properly uncovered and managed, most likely it will evolve toward one of the two collaborative extremes—(1) collaborative overload, which is characterized by a disproportional collaborative state of some project stakeholders related to others of a given project social network and may lead to the emergence of information bottlenecks and information exchange delays, just to name a few, and (2) lack or nonexistence of collaboration, which is characterized by the lack of collaborative initiatives within a project social network, which ultimately may lead to the emergence of organizational silos, for example [29]. Both information bottlenecks and organizational silos are known for having drastic negative impacts on organizations.

Furthermore, the proposed metrics use a very straight-forward and simple mathematical formulation rather than a complex system of algorithms, which benefits organizations regarding the cost-benefit of the application of such metrics.

Still, organizations can use the results outputted by the proposed graph-based centrality metrics in this work to correlate project stakeholders' behavioral patterns with project outputs and outcomes. By doing so, organizations learn in a straightforward and insightful way (lessons learned), which behavioral patterns must be replicated in future projects and which of them must be eliminated or avoided in order to increase project success outcome.

Finally, organizations benefit from the application of the proposed metrics because proposed metrics generate unique and actionable know-how in the collaborative project dimensions, which very likely will give organizations a sustainable competitive advantage when compared with other organizations that do not have such insights enabled by the application of the proposed metrics. As a direct consequence, this will directly contribute to the three typical pillars of sustainability (society, profit, and environment) because working in a more efficient way enables the timely identification of project behavior patterns that very likely may lead to failure, for example, an organization can take actionable measures to avoid the heading to a failure outcome and thus saving resources (time, energy, and people) that would be needed in order to rework or redo project tasks and activities or rescope a project.

In the academic dimension, the proposed metrics in this work will enable us to better understand the people aspect implications in a project's outputs and outcomes, which may lead to the development of novel project behavioral theories and approaches in order to better and wiser manage projects. The development of new graph-based centrality metrics may also trigger research organizations to invest more in the development of new algorithms that are able to capture project behavioral patterns in a 360° approach.

6. Conclusions

In this work, seven graph-based centrality metrics are proposed to analyze in a quantitative way five key collaborative project dimensions that emerge and evolve across a project lifecycle. The five key collaborative dimensions result from a survey conducted between 2018 and 2021 with 700 international project stakeholders from eight different business sectors. The conducted research in this work addresses one of the three aspects (the people aspect) that project management academicals and practitioners argue as critical to better understand how projects can be successfully delivered. More concretely, the people aspect relates to the impacts of project stakeholders' collaboration on project outputs and outcomes. The research analyzes the emergence and evolution of the mix of formal and informal networks within an organizational project social network, and how these drive behavioral patterns in all the different phases of a project lifecycle. Across the case study section, the calculation process of the seven proposed centrality metrics is illustrated in a step-by-step approach. The calculation process is simple to execute, and the results uncover unique and insightful behavioral patterns that help to characterize the five different key collaborative project dimensions.

Regarding future research, we suggest three critical areas. First, regarding the data collecting methods, further research should be conducted in order to develop collecting methods that minimize or eliminate bias as participants are responding to project surveys. In this respect, research should be undertaken in order to develop strategic questions and counter-questions that allow the researcher to identify any type of potential bias in the provided answers. Second, research should be conducted not only in the development of new and adapted graph-based centrality metrics to better mirror the myriad of informal relationships that emerge and evolve as people work together to deliver project objectives but also graph-based dispersion metrics. Finally, alternative data-collecting methods that capture relational data from other sources that are, until today, restrained due to the GDPR (General Data Protection Regulation) regulations, such as phone calls and corridor meetings, for example, should be developed.

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A Reputational-Risk-Based Match Selection Framework for Collaborative Networks in the Logistics Sector

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Abstract: Collaborative networks in the logistics sector have proven to be a solution that both meets environmental footprint reduction goals and addresses the impact of rising fuel prices on logistics companies, especially for small- and medium-sized enterprises. Despite these benefits, these collaborative networks have not received the desired amount of participation due to reputational risk. This paper develops a framework for assessing and managing reputational risk to encourage logistics companies' participation in collaborative networks. To this end, customer satisfaction factors were correlated with logistics operations, and this correlation was then modeled using the Bowtie method, fault trees, event trees, reliability theory, and the Monte Carlo model. The results show that it is possible to implement a structured model that can be easily put into practice. Using an illustrative case study, it is also possible to prioritize three companies according to their reputational risk as assessed by the proposed model. The developed model can promote the sustainability of collaborative networks in the logistics industry by assessing and consistently reducing reputational risk, thus supporting the strengthening of the relationship between suppliers, logistics service providers, and end customers.

Keywords: sustainability; collaborative networks; logistics; transportation sector; risk assessment and management; Monte Carlo method

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1. Introduction

Collaborative networks in the logistics sector have proven to be a solution that meets the goal of reducing both the environmental footprint and the impact of rising fuel prices on logistics companies, especially for small- and medium-sized enterprises. Despite these benefits, these networks have not received the desired amount of participation due to reputational risk. This fact has in some ways limited the capacity of these collaborative networks and reduced their effectiveness in contributing to the sustainability of societies.

Sustainability can be described as a set of strategies to meet the present needs of society without compromising the ability of future generations to meet their own needs [1]. This concern for future generations has grown in recent years as a result of active societal awareness and regulatory initiatives aimed at promoting sustainability.

The main fields of action for sustainable development are the reduction in the consumption of raw materials and products, the increase in the reusing and recycling of products, and the reduction in waste in the most diverse sectors of industry, especially from energy consumption, which improves natural resources' sustainability and reduces the carbon footprint [2].

In fact, the negative impact of excessive energy consumption due to technological development and economic growth is the main cause that led to the creation of various environmental initiatives around the world. These impacts range from global warming to the environmental burdens of extracting and transporting fossil fuels [3].

To mitigate these impacts, regulators have established standards to reframe industry thinking and strategies, sometimes resulting in additional efforts for companies. For example, limiting emissions from internal combustion engines has challenged automakers to develop new, more fuel-efficient and environmentally friendly engines to replace engine models that are still in the early stages of their life cycle and have a high level of reliability. This fact has a negative impact on these companies, as the expected life cycle of the engines is shorter than estimated, which reduces the financial return on investment from development and production [4].

Another example is taxes on fuels. The tax burden on fuels in Europe varies between 50.8% and 66.5% depending on the country and the type of fuel, which are very high taxes aimed at reducing fuel consumption in order to reduce CO^2 emissions. However, these strategies have a negative economic impact on companies, end users, and society in general, so alternative strategies are needed to mitigate or avoid these types of impacts as a result of regulatory initiatives, especially for small- and medium-sized enterprises (SMEs). These companies play an important role in the economy of societies. In many countries, SMEs represent around 87% of companies, playing a key role in the economy, creating jobs, promoting economic growth, and contributing significantly to gross domestic product (GDP). However, despite their important role in the economy, these companies have some weaknesses and are very sensitive to market fluctuations and regulatory adjustments. In addition to these external factors, SMEs have some internal weaknesses such as difficulties accessing financing, a lack of manpower, a lack of efficient management, inadequate infrastructure, and obsolete technology, among others. Due to the limitations faced by SMEs, support and incentive programs have been created over the last few years to promote the growth of these companies by encouraging smart growth (industry 4.0), the implementation of sustainable strategic decisions, and the adoption of inclusive policies [5].

On the one hand, these incentives are intended to support SMEs, but on the other hand, regulatory initiatives that aim to promote sustainable development create additional challenges for these companies. The solution is not to eliminate regulatory initiatives, but instead to create solutions to overcome these additional challenges.

For example, the transport industry has a major impact on the ecological footprint, contributing heavily to the greenhouse effect, and due to this fact, it is directly affected by regulatory initiatives. The continuous increase in fuel prices and taxes on the acquisition and maintenance of vehicles has reduced the profit margins of these companies. On the other hand, alternative vehicles powered by electricity or hydrogen still do not offer operating conditions compatible with the operational needs of this industry. As a result, these companies are under pressure to reduce their contribution to the ecological footprint, but the existing alternatives are not operationally viable, especially in the land freight sector.

Taking the case of Portugal as an example, small- and medium-sized companies in the land transport sector represent around 1.6% of Portuguese SMEs with a pre-pandemic turnover of around 7.5 billion euros, according to a Bank of Portugal report published in 2020 [6]. According to the same report, when comparing the financial autonomy of SMEs in the transport sector with other SMEs in Portuguese industry, it can be seen that, over the last decade, the ability of these companies to meet their financial commitments through equity (financial autonomy) was always lower than that of SMEs from other sectors, indicating that this sector has lower profit margins compared to others.

However, from 2011 to 2017, SMEs in the freight transport sector followed the other sectors in a growing trend towards increased financial autonomy, despite still having a lower degree of autonomy. After 2017, this trend diverged significantly; the other sectors continued to show a positive growth rate, and the transport sector started to show a negative growth rate. Between 2017 and 2020, the financial autonomy of these companies

was 29.4% in 2017, 28.6% in 2018, 27.19% in 2019, and 13.14% in 2020, respectively. The results for 2020 were the lowest values recorded in the decade 2010–2020. This decrease in financial autonomy results from the change in the trend of the price of diesel in 2016; since 2012, the annual trend in the price of this fuel had been decreasing, but in 2016, this trend was reversed, moving to a positive price change rate [7].

In practice, the freight transport sector is very sensitive to changes in fuel prices, which can jeopardize the survival of small- and medium-sized companies in this sector. Despite the importance of the freight transport sector for the proper functioning of the economy, government aid to these SMEs in the form of reduced taxes on fuels cannot directly solve the problem, because, in this way, they would be promoting an increase in the ecological footprint and going against the UN's 2030 Agenda. This can be considered an industrial problem with negative impacts both on the sustainability of the sector and on the growth of the economy in general. The development of sustainable solutions to eliminate or mitigate these impacts is of the utmost importance [8].

To solve this logistical problem and reduce operating costs, researchers have proposed new management models based on collaborative approaches which meet one of the 17 objectives of the UN, namely the development of partnerships in the implementation of the UN goals. The main objective of these models is to reduce waste in the transport of goods, also known as "empty running" [9,10].

According to the UK Department of Transport, capacity utilization between 2006 and 2016 was 68%, and freight transport efficiency was 48%. The same report indicates that "empty running" waste has been gradually increasing. One of the reasons for this increase is the concern of suppliers for final customer satisfaction. High levels of satisfaction promote customer loyalty, and in this sense, suppliers have pressured logistics operators for faster deliveries. This in turn promotes "empty running" waste because the time to guarantee the "full running" condition is increasingly reduced [11].

The development of collaborative models in logistics intends to face this problem through the creation of virtual companies that manage collaborative logistics networks. These companies aim to manage information related to the participants of the collaborative network by evaluating the available transport space and respective routes, optimizing route selection according to the logistics mission, and selecting the match between the mission and the logistics operator that results in the best performance of the network.

For these collaborative networks to be efficient, it is necessary that the network has as many participants as possible, so that the size of the network's resources has a dimension that allows for the sustainability of the network. The problem is that the participation in these collaborative networks has been relatively low, making it difficult to create coalitions, particularly for small- and medium-sized enterprises, as they are relatively vulnerable to negative impacts; it is because of this that they tend not to adopt strategies of great uncertainty [12]. These facts have been reinforced by the strong competition verified in the sector; therefore a strong strategy is necessary to promote trust between the participating entities in the collaborative network, since for the correct functioning of these collaborative networks, it is necessary to share sensitive information such as costs, needs, and the cost/benefit ratio, among other information [13]. In this sense, the development of risk analysis and management models that make it possible to assess and manage uncertainty in the selection of the match between entities for a given mission is of great importance to promote trust between existing participating entities in the network and to promote the participation of new entities in the collaborative network.

This work fills the research gap on collaborative networks in the logistics sector, where reputational risk has negatively affected logistics companies' participation in these networks. To this end, a model of reputational risk was developed to encourage the participation of potential companies in collaborative logistics networks, with a focus on small- and medium-sized enterprises to increase the capacity of these networks. This model aims to evaluate and manage the reliability of the decisions made in selecting the most suitable companies for a given task. The selection of the right partner within the network is

extremely important to minimize the risks for both the participants and the collaborative network. This selection cannot be completed in the same way for all missions. A range of events must be considered that vary over time, such as political, social, economic, technical, and financial events. The proposed model is a quantitative model and is developed using reliability theory along with the Monte Carlo model. The approach to developing the model focuses on the key risk factors identified based on the typical business models that are seen in collaborative logistics networks. To illustrate the application of the model, a case study was developed to analyze and discuss the robustness of the model.

2. Literature Review

In this section, a literature review is conducted on two knowledge areas. One focuses on collaborative networks, and the other on risk analysis and management tools. At the end, some risk factors related to collaborative networks are identified and analyzed to be used in the proposed reputational risk model.

2.1. Collaborative Networks

Collaborative networks are organizational systems capable of bringing together individuals and institutions in a participatory manner for related purposes. They are flexible structures and are horizontally structured [14]. Originally, they were created with the aim of reducing uncertainty and risk and organizing economic activities through coordination and cooperation between companies. The implementation of collaborative processes has accelerated in recent years due to new business challenges, rapid socioeconomic change, and new developments in information and communication technology [15].

There are different types of collaborative networks, the most common of which are social networks that focus on relationships between social entities; virtual organizations, which include a number of independent organizations that share resources and capabilities to achieve a common goal; virtual enterprises, which emerge from a temporary alliance of organizations that share capabilities and resources to respond more efficiently to market opportunities; agile enterprises, where the organization's ability to continuously adapt in an environment of unpredictable change results from cooperative strategies; joint ventures, in which several companies temporarily combine into a single entity to jointly carry out an economic activity; and finally, the collaborative network of the cluster type, in which there is a geographical concentration of interrelated companies operating in the same sector and sharing not only the location but also the responsibility for the development of products and services [16].

For collaborative networks to be successful, they must meet a number of requirements to ensure network sustainability. In particular, the companies that are part of the network must be willing to share information, make synchronized decisions, promote the fair sharing of profits, update and share their capacities, have integration policies, align their goals with those of the other companies in the network, plan strategies and objectives together, foster trusting relationships, and maintain open and fair communication. All of these requirements have a certain level of risk that may negatively affect the companies that participate in the network [17].

On the other hand, there are a number of factors that can hinder the effective functioning of collaborative networks or jeopardize their sustainability, namely, lack of trust, impersonal and poor relationships, inconsistent business strategies, a mentality limited to processes without considering a holistic view, inaccurate information, and poor communication channels. Of these factors, a lack of trust has the greatest impact on the collaboration network, as it strongly encourages network collaborators to leave the network. In the majority of cases, this factor increases the sense of risk regarding the company's participation in the network [18].

The benefits of membership in collaborative networks depend on the network's area of activity. However, there are some benefits that can be considered universal and independent of the area of activity. For example, belonging to a collaborative network can

increase the efficiency and effectiveness of the company, promote its expansion, improve its communication, increase the quality of its work processes, increase the reliability of the company's operations, increase its creativity and productivity, and, most importantly, promote the financial profit of the company [19].

The literature is replete with work addressing the inherent risks of collaborative networks in a variety of domains, such as works promoting sustainable systems related to innovation in collaborative networks [20], modeling risks related to collaborative networks to determine the likelihood and impact of projects [21], modeling risks related to information sharing, information management, and knowledge [22], incorporating heuristic models to analyze and manage risks in collaborative networks [23], and identifying the benefits of applying risk models in collaborative networks [24]. Despite the extensive amount of work in the literature and to the best of the authors' knowledge, no reputational risk model developed for collaborative networks in the logistics sector can be found in the literature. In this sense, the work developed in this study is innovative and fills a knowledge gap in risk assessment and management of collaborative networks.

2.2. Risk Assessment and Management

According to the International Organization for Standardization's 31000 standard (ISO 31000), organizations of all types and sizes face internal and external factors that can jeopardize the achievement of their goals and expectations. These factors always have an associated level of uncertainty and impact, and their aggregate assessment represents the so-called risk that organizations face [25].

Risk assessment aims to support decision making in all activities of an organization. All activities involve a certain level of risk, and its management intends to control this level through logical and systematic treatment actions. Although the interpretation and management of risk is an intrinsic human capacity, it is limited when several risk factors are simultaneously involved in decision making, i.e., aggregate risk assessment requires the use of appropriate tools as well as a logical and systematic framework in order to make possible the correct interpretation of decision making.

Organizations benefit greatly from the application of risk analysis and management practices in their most varied activities. For example, it increases the likelihood of achieving their objectives, improves the identification of opportunities and threats, improves governance, increases confidence, minimizes losses, improves the efficiency of operations, and so on [26].

Despite the benefits inherent to risk analysis and management methods, their application to collaborative networks is somehow limited, especially for collaborative networks in logistics. In the literature, one can find a reasonable number of works related to collaborative networks in logistics, but there are few works that include collaborative risk analysis and management as an integral part of their model proposals; in this sense, there is limited knowledge in this area of investigation.

However, collaborative risk management has begun to gain a modest momentum in the literature. According to [27], in a time window of 21 years, from 1996 to 2017, 53 articles on collaborative risk management were published outside the scope of supply chain and operations management, and only 23 focused on this topic, demonstrating a modest growth trend. The most important research topics covered have been on sharing information, standardization procedures, decision synchronization, incentive alignment, supply chain and process integration, and collaborative system performance.

According to the same authors, and despite the inherent advantages of collaborative risk assessment and management, a clear and effective definition of collaborative risk management as well as a clear demonstration of its respective advantages is lacking in most of the works published in this time window; this fact may be at the origin of the trend found.

Another possible reason could be the fact that collaborative networks are complex systems whose risk is modeled through the selection of models that best suit the scenario,

or a tailor-made approach. In this sense, there is no "one-size-fits-all" solution to assess the risk inherent to systems, and this fact may also be at the origin of the aforementioned trend.

In the literature, a wide range of risk assessment and management models can be found alongside strong evidence of their acceptance in academia [28]. These models can be divided into three broad categories, namely, quantitative models, qualitative models, and mixed models employing both qualitative and quantitative approaches. In practice, quantitative models are more appropriate for scenarios where it is not possible to have statistical data, while quantitative models need statistical data to be used. Mixed models take advantage of the inherent advantages of both approaches. The analysis and risk management of systems, due to its multidisciplinary nature, normally needs to use the three approaches to assess the aggregate risk, which increases the complexity of the problem [29].

The most well-known and used qualitative model in the industry is Failure Mode and Effects Analysis, or in short, FMEA. This model was developed by the US Army in the decade following World War II, the 1950s, and was first developed as a structured technique for failure analysis in order to increase the reliability of military equipment. Nowadays, its application is almost universal, verifying its applicability from the nuclear industry to health care. Despite this great success, this risk management method has many limitations inherent in its qualitative nature and inherent to its function of prioritizing failure modes, also known as the Risk Priority Number (RPN). Its success is due to its ease of being learned and applied to real cases, and many of the limitations pointed out in the literature are usually overcome through alternative methods [30–32].

On the opposite side, on the side of quantitative models, we have the Monte Carlo model, which is derived from Buffon's needle problem as stated in the 18th century. In 1940, Stanislaw Ulam developed the modern version of the Monte Carlo method that makes use of random experiments to determine the parameters of the statistical distribution that models a given event [33]. The method, like the FMEA, is well known in the industry, with practical applications from finance to the nuclear industry. It has a slower learning curve and requires prior knowledge of statistics to be used, which is not the case with FMEA. However, this model makes it possible to assess the aggregate risk of a given system, regardless of its complexity.

Another quantitative model widely used in the assessment of aggregate risk is called Failure Tree Analysis (FTA) [34], a method invented in 1961 at Bell Laboratories. This model makes use of the reliability block theory to assess the aggregated probability of systems failure. In a similar way, Event Tree Analysis (ETA) [35], another quantitative method invented in 1974 during the WASH-1400 nuclear power plant safety study, assesses the probability of a given impact considering all possible paths that lead to that impact.

These models seem similar but have different paradigms: fault tree analysis characterizes the system from the perspective of preventing a given event from occurring, while event tree analysis characterizes the system from the perspective of avoiding impacts given that an event has already occurred.

In practice, these two methods have been used together as a way to assess the aggregate risk of systems through the Bowtie model [36]. This model is a diagram that establishes a relationship between basic events and the impacts of the respective top event. It takes into account prevention and mitigation barriers, and because of that, it is one of the most robust frameworks for risk assessment and management.

An example of a risk assessment and management tool that allows the assessment of aggregate risk through a mixed approach (quantitative and qualitative) is the fuzzy logic method [37]. This method began to be studied in 1920 by the authors Lukassiewicz and Tarski and was later introduced in the literature in 1965 by Lotfi Zadeh. It uses the human interpretive paradigm to model the behavior of systems. It uses linguistic variables, membership functions, and rules of inference, evaluated qualitatively, to infer about the system's outputs as a result of the aggregated contribution of each system component. It is a method that has proven itself in the most varied areas of industry, from artificial intelligence to medical decision making.

2.3. Risk Factors in Logistics

The literature mentions that participation in collaborative networks in the field of logistics has had little appeal due to uncertainty about the quality of the services provided by network operators [38]. This uncertainty results, in part, from the lack of indicators showing the quality level of operators. In collaborative networks, the choice of a particular operator for a given logistical task is essentially based on operational parameters such as cost and time [39]. However, this strategy does not take into account the fundamental concerns of the companies that need the logistics service and of the companies that provide the logistics services. Figure 1 shows several factors that cause concern among logistics companies. These results show that reputational damage and third-party responsibility in the provision of logistics services are two factors of real concern for companies and play an important role in their decisions.

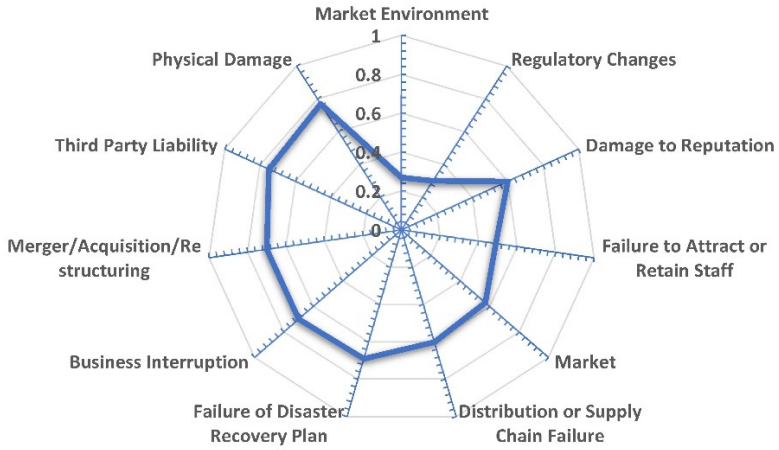

Figure 1. Risk factors identified by logistics companies and their respective weightings, evaluated according to their impact on the companies' objectives, with information gathered from [40].

In a sense, these two factors can be combined, because the lack of third-party liability affects the reputation of the company that contracts other companies. In this way, the sum of the liability factor and the reputational damage factor results in a factor with the highest weight among the factors shown in Figure 1.

The impact on reputation extends to very different areas of logistics, as Figure 2 summarizes. In this sense, the assessment of reputational risk becomes essential for the decision making of companies in their interactions with third-party companies and also for the assessment of the quality of the services provided by the company itself.

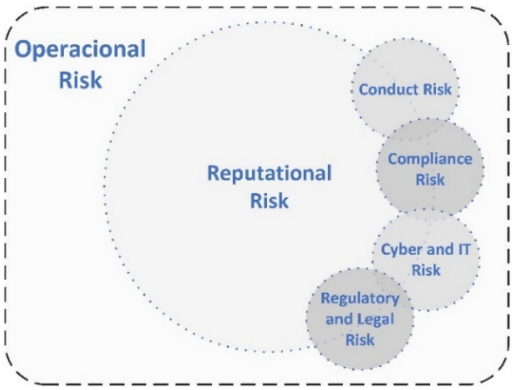

Figure 2. Logistic risk areas.

In this sense, it is important to develop a model for assessing reputational risk in order to support decision making and to promote the participation of companies in collaborative

networks. The benefits of such participation are widely discussed in the literature and have been shown to be positive in practice [41]. However, the participation of small- and medium-sized enterprises in collaborative logistics networks is low, despite the benefits that can result from such participation. In this work, we intend to develop a reputational risk assessment framework to reduce uncertainty in the participation of small- and medium-sized enterprises in collaborative logistics networks. The expected outcome of applying the framework is an increase in the number of participants in collaborative logistics networks as well as the further participation of companies that are already part of the network.

3. Research Methodology

This section presents the step-by-step process for developing the proposed reputational risk model.

3.1. Collaborative Networks in Logistics and Their Relationship with Reputational Risk

Several business models for collaborative logistics networks have been proposed in the literature [42]. Essentially, in its most general form, a network is managed by a virtual enterprise that manages the information provided by its participants. The virtual enterprise is responsible for ensuring the security and confidentiality of this information. It is also responsible for selecting the most appropriate network participant for a given logistics mission. Logistics missions can be brought to the network in two ways: first, by external customers who need the service; and second, by network participants who have a service order from their customers and offer this order to other network operators for execution. Figure 3 illustrates, in simplified form, the functional system of a collaborative network in logistics. The demand party asks the supplier to deliver goods via a logistics service provider selected by the virtual company responsible for managing the collaborative network.

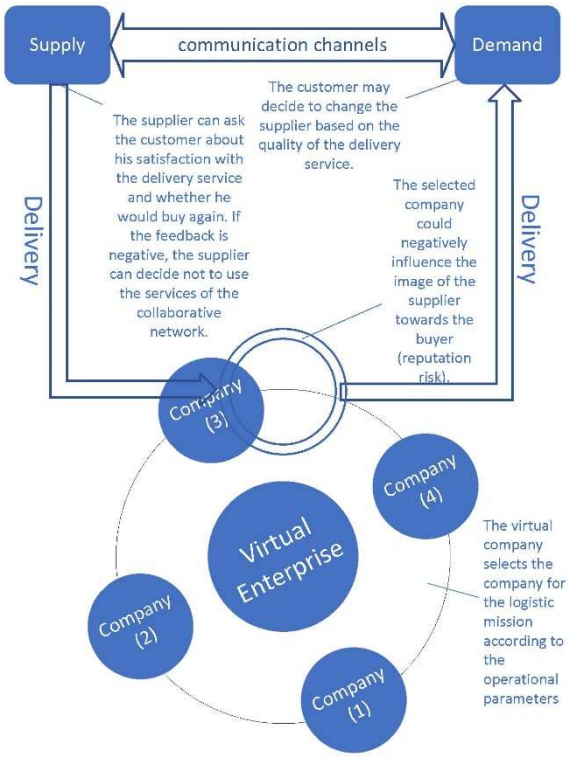

Figure 3. Collaborative network in logistics.

The relationship between the customer and the company that supplies the goods is strongly influenced by a number of factors that may or may not promote the continuity of this relationship. The most important factors are customer satisfaction, the trust that the supplier conveys to the customer, the loyalty between the supplier and the customer, the

communication of feedback, and the publicity that customers give about the supplier. In general, these factors can be negatively affected by the services offered by the collaborative network. For example, customer satisfaction can be affected by delivery delays or the loss of goods during the logistics mission. If the logistics company does not report delays efficiently and does not have alternative mechanisms to mitigate these delays, or does not quickly recover lost goods, the customer may decide to switch suppliers. Although the supplier is not to blame for the poor logistics service, the negative impact is ultimately attributed to the supplier. After all, the supplier is responsible for selecting the logistics company that will deliver the product, and it is also responsible for assessing the quality of the transportation and delivery service that it offers to its customers. In this way, the supplier is ultimately strongly influenced by the quality of the services provided by the logistics company.

On the other hand, logistics companies with a loyal customer portfolio based on a history of trust and a high level of satisfaction find it difficult to outsource logistics tasks to third parties whose quality level is uncertain. For these logistics companies, the impact of negative third-party performances could also negatively affect their customer portfolio and threaten their survival as a business. Indeed, reputational risk has a transversal scope, with implications for the suppliers' and customers' sides as well as the logistics companies' side, and ultimately for the sustainability of the collaborative network. In this sense, the framework developed in this work to assess reputational risk responds to a real need that exists in the practice of managing collaborative networks in logistics.

3.2. Proposed Approach

The approach taken in developing the reputational risk assessment framework begins by identifying the key drivers of customer satisfaction with respect to logistics services. It then identifies the logistics operations that may negatively impact these factors in some way. The next step is to examine the causal relationship between the customer satisfaction factors and logistics operations and determine the impact of each logistics operation on customer satisfaction. The causal relationship is modeled with the Bowtie method using the fault tree and event tree methods, and reliability theory is used to determine the aggregate reputational risk. Finally, the Monte Carlo method is used to prioritize companies based on their reputational risk. Figure 4 shows the diagram illustrating the approach used in developing the framework.

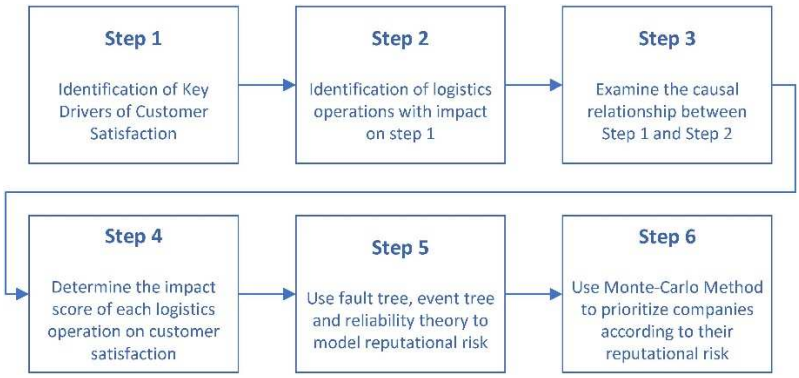

Figure 4. Main steps of the implemented framework to prioritize logistics companies according to their reputational risk.

3.2.1. Framework Step 1—Identifying the Most Important Factors for Customer Satisfaction

The factors that have the greatest impact on customer satisfaction while still being sensitive to logistics operations were identified through a literature review [43–47]. Eleven factors were identified, which were divided into four categories, namely, information service, customer service, distribution service, and cross-border service. In the information

service category, the factors of transparency, security, and customization of information were identified. These factors strengthen customer trust and loyalty.

In the distribution service category, the following factors were identified: accuracy, compliance with estimated delivery times, and the safety of transported goods (securing goods against theft). This category is directly related to the logistics services provided by the collaborative network and is sensitive to the level of quality in the provision of logistics services by the network collaborator. In the category of cross-border services, the factors international services and international relations were identified. This category refers to the ability of the logistics company to protect the interests of their customer.

Finally, in the customer service category, the factors of error correction, packaging (protecting goods against accidents), and value-added services were identified. This category refers to customer loyalty and customer recovery. Figure 5 shows the 4 categories mentioned above as well as the 11 factors distributed among the respective categories.

Figure 5. Customer satisfaction factors that may be affected by logistics services.

3.2.2. Framework Step 2—Identify the Logistics Operations That Impact Customer Satisfaction

Similar to the identification of customer satisfaction factors, bibliographic research was also conducted to identify the logistics operations that may negatively affect the customer. The identified operations were classified into three categories, namely, order processing, warehousing and transportation [43–47].

In the order processing category, order processing (the process or workflow that occurs after a customer places an order), management (the process of entering, tracking, and fulfilling customer orders), and post-processing (the management of customer information and services provided for a particular logistics mission) were identified. This category refers to the interaction with customers, i.e., the end customer and the supplier. In the warehousing category, the operations of storage, handling (the loading and unloading of cargo within the warehouse), picking, and packaging were identified. This category is related to the integrity of the transported products and the reliability of the logistics company. Finally, in the transport category, the operations for loading, transport, and delivery were identified. This category is related to the quality of transport and delivery services. Figure 6 shows a schematic representation of the three categories of logistics operations and their respective processes.

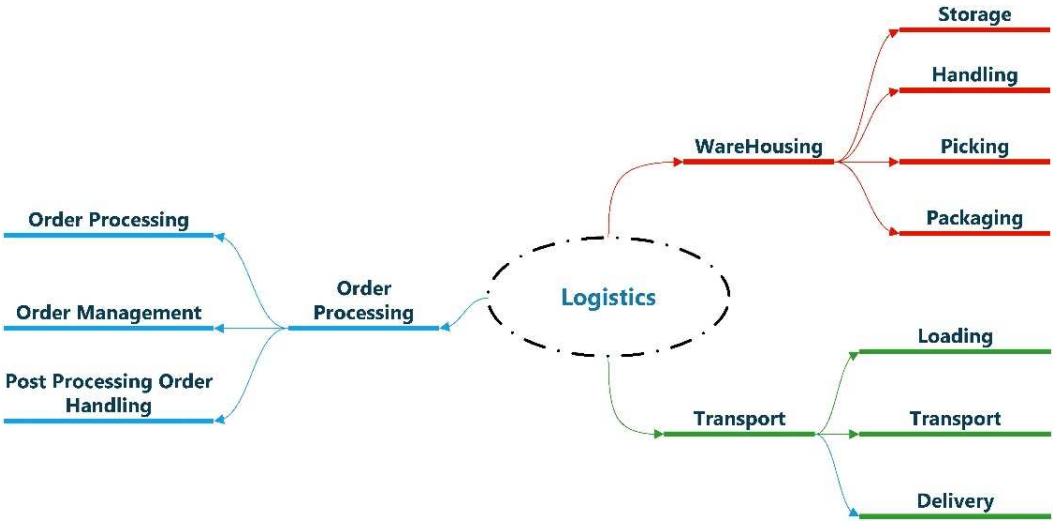

Figure 6. Logistic operations that may create negative impacts on customer satisfaction.

3.2.3. Framework Step 3—Identifying Causal Relationships between Customer Satisfaction and Logistics Operations

Having identified customer satisfaction factors and their associated logistics operations, the next step is to determine the causal relationship between these factors and logistics operations. Table 1 presents this relationship in the form of a matrix. The causal relationship was determined through an inferential analysis, together with the logical conclusions and appropriate consequences.

The service processing of logistics operations (*OP1*) can negatively impact customer satisfaction in the categories of service quality (*SQ*), distribution quality (SDQ), and cross-border service quality (*CBSQ*). It can have a negative impact on the transparency of information (*SQ1*), the correctness of operations (*DSQ1*), and also on the measures required for cross-border legal processing (*CBSQ2*).

Service order management in logistics (*OP2*) has a direct impact on the security of customer information (*SQ2*), on the accuracy of logistics operations (*DSQ1*), on the timely delivery of goods (*DSQ3*), and also on cross-border operations (*CBSQ2*). Poorly managed service orders can lead to the disclosure of customer information and also cause delays in logistics processes at home and abroad.

Post-processing (*OP3*) affects all factors in the *SQ* and *CBSQ* categories. It also affects the customer service (*CSQ2*) and value-added (*CSQ3*) factors.

When analyzing the storage category (*WH*), it was found that storage can negatively affect the accuracy of logistics services (*DSQ1*) and the safety of goods (*DSQ2*). Handling can also affect the safety of the goods (*DSQ2*). The process of selecting goods can negatively affect the factors of accuracy (*DSQ1*) and packaging (*CSQ1*). Finally, packaging logistics may affect the packaging satisfaction factor (*CSQ1*).

In the last category of logistics operations (*T*), shown in Table 1, it was found that the logistics operation of loading (*T1*) can negatively affect the accuracy of operations (*DSQ1*) and the safety of transported goods (*DSQ2*). On the other hand, the transportation operation (*T2*) can negatively affect the timely delivery of the goods (*DSQ3*). Finally, the delivery operation (*T3*) may negatively affect the safety of the delivered goods (*DSQ2*).

Table 1. Causal relationships in matrix form between customer satisfaction and logistics operations.

		Service Quality (*SQ*)			**Distribution Service Quality (*DSQ*)**			**Customer Service Quality (*CSQ*)**			**Cross-Border Service Quality (*CBSQ*)**	
		(SQ1) Information Transparency	**(SQ2) Consumer Information Security**	**(SQ3) Logistics and Customs Information Level**	**(DSQ1) Accuracy**	**(DSQ2) Safety of Goods**	**(DSQ3) On-Time Deliveries**	**(CSQ1) "fedex" Packing**	**(CSQ2) Error Handling**	**(CSQ3) Value-Added Services**	**(CBSQ1) International Logistics Services**	**(CBSQ2) Policy and Regulatory Level**
Order processing (*OP*)	(OP1) Order Processing	***OP1-SQ1***			***OP1-DSQ1***							***OP1-CBSQ2***
	(OP2) Order Management		***OP2-SQ2***		***OP2-DSQ1***		***OP2-DSQ3***					***OP2-CBSQ2***
	(OP3) Post processing order handling	***OP3-SQ1***	***OP3-SQ2***	***OP3-SQ3***					***OP3-CSQ2***	***OP3-CSQ3***	***OP3-CBSQ1***	***OP3-CBSQ2***
WareHousing (*WH*)	(WH1) Storage				***WH1-DSQ1***	***WH1-DSQ2***						
	(WH2) Handling					***WH2-DSQ2***						
	(WH3) Picking				***WH3-DSQ1***			***WH3-CSQ1***				
	(WH4) Packaging							***WH4-CSQ1***				
Transport (*T*)	(T1) Loading				***T1-DSQ1***	***T1-DSQ2***						
	(T2) Transport						***T2-DSQ3***					
	(T3) Delivery					***T3-DSQ2***						

3.2.4. Framework Step 4—Impact Score of Individual Logistics Operations on Customer Satisfaction

The basic definition of risk states that the magnitude of the impact of a given event must be determined and then related to its corresponding probability in order to evaluate the risk of that event [25]. In this sense, Table 2 shows the degree of impact that each logistics operation has on the different categories of customer satisfaction. These values were assigned qualitatively on a scale of 1 to 3.

Table 2. Impact scores of individual logistics operations on customer satisfaction.

	Area	Item	Score
Customer Satisfaction	Information service quality	Information Transparency	2
		Consumer information security	3
		Logistics and customs information level	1
	Distribution service quality	Accuracy	2
		safety of goods	3
		on-time deliveries	3
	Customer service quality	fedex packing	2
		Error handling	3
		Value-added services	1
	Cross-border service quality	International logistics services	3
		Policy and regulatory level	2

3.2.5. Framework Step 5—Modeling Reputational Risk with Bowtie, Event Trees, Fault Trees, and Reliability Theory

In this step, the causal relationship shown in Table 1 is represented by Bowtie diagrams for each of the 10 logistics operations listed in the second column of Table 1. Figures 7–9 show the 10-operation bowtie schematically, considering the above causal relationship. For each bowtie, expressions of the risk associated with each logistics operation are generated considering the impact values presented in Table 2 and the overall probability determined by the methods of fault trees, event trees, and reliability theory.

Each bowtie starts with the probability of failure for a given logistics operation, and then the probability of failure for the prevention barriers is considered. The purpose of these barriers is to prevent a failure in the logistics operation from leading to an event with a negative impact on customer satisfaction. The evaluation of the probability that an event with a negative impact on customer satisfaction will occur is evaluated using the fault tree method and reliability theory. If the prevention barrier cannot prevent this event from occurring, then the mitigation barriers can mitigate or even eliminate this impact. These barriers also have a probability of failure and must be included in the overall risk assessment of each bowtie, where the probability of the event occurring is considered along with the event tree method and reliability theory to assess the overall risk of each bowtie.

Equation (1) represents the aggregate risk of logistics operations in the order processing category (*OP*). This equation is made up of three components. The first component represents the aggregate risk of logistics operation *OP1*, the second component represents the aggregate risk of logistics operation *OP2*, and the last component represents the aggregate risk of logistics operation *OP3*. The aggregated risk of the category OP results from the sum of these three components.

$$OP_{risk} = \begin{array}{c} P_{FOP1} \cdot P_{PB\_OP1} \cdot \left(P_{MB\_SQ1} \cdot I_{SQ1\_score} + P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_CBSQ2} \cdot I_{CBSQ2\_score}\right) \\ + \\ P_{FOP2} \cdot P_{PB\_OP2} \cdot \left(P_{MB\_SQ2} \cdot I_{SQ2\_score} + P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_DSQ3} \cdot I_{DSQ3\_score} + P_{MB\_CBSQ2} \cdot I_{CBSQ2\_score}\right) \\ + \\ P_{FOP3} \cdot P_{PB\_OP3} \cdot \left(P_{MB\_SQ1} \cdot I_{SQ1\_score} + P_{MB\_SQ2} \cdot I_{SQ2\_score} + P_{MB\_SQ3} \cdot I_{SQ3\_score} + P_{MB\_CSQ2} \cdot I_{CSQ2\_score} + \right. \\ \left. P_{MB\_CSQ3} \cdot I_{CSQ3\_score} + P_{MB\_CBSQ1} \cdot I_{CBSQ1\_score} + P_{MB\_CBSQ2} \cdot I_{CBSQ2\_score}\right) \end{array} \quad (1)$$

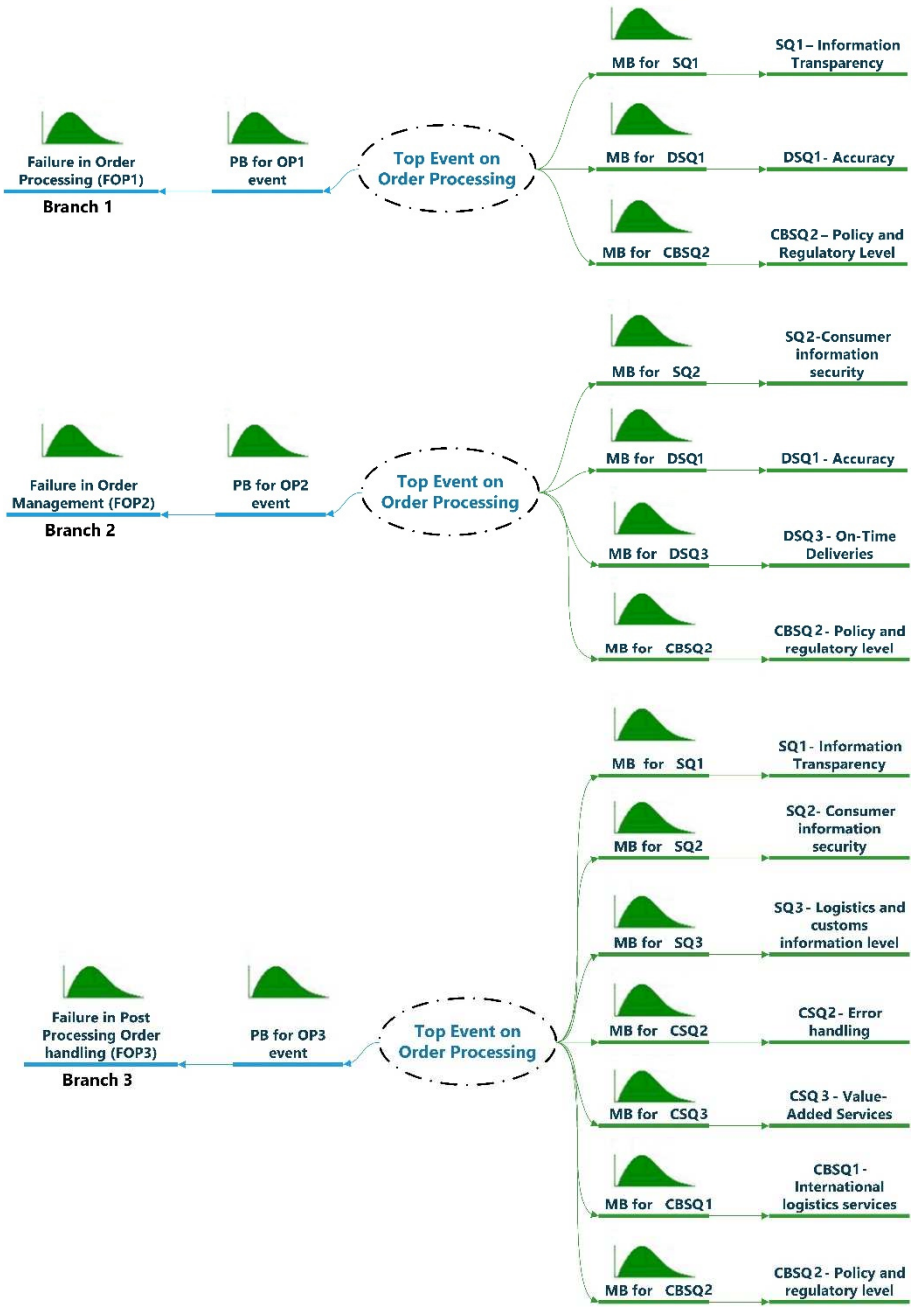

Figure 7. Bowtie diagrams for the processing order category. *PB* stands for preventive barrier, and *MB* stands for mitigation barrier.

Figure 8 shows the four bowties developed for the warehouse category, and Equation (2) represents the overall risk for this category. Similar to what is described in Equation (1), Equation (2) is composed of four components that represent the aggregate risk of the four bowties developed for this category. In this sense, the first component represents the aggregate risk of the storage operation, the second component represents the aggregate risk of the handling operation, the third component represents the aggregate risk of the picking operation, and finally, the fourth component represents the aggregate risk of the packaging operation. The total risk of the warehouse category is also the result of adding together these four components.

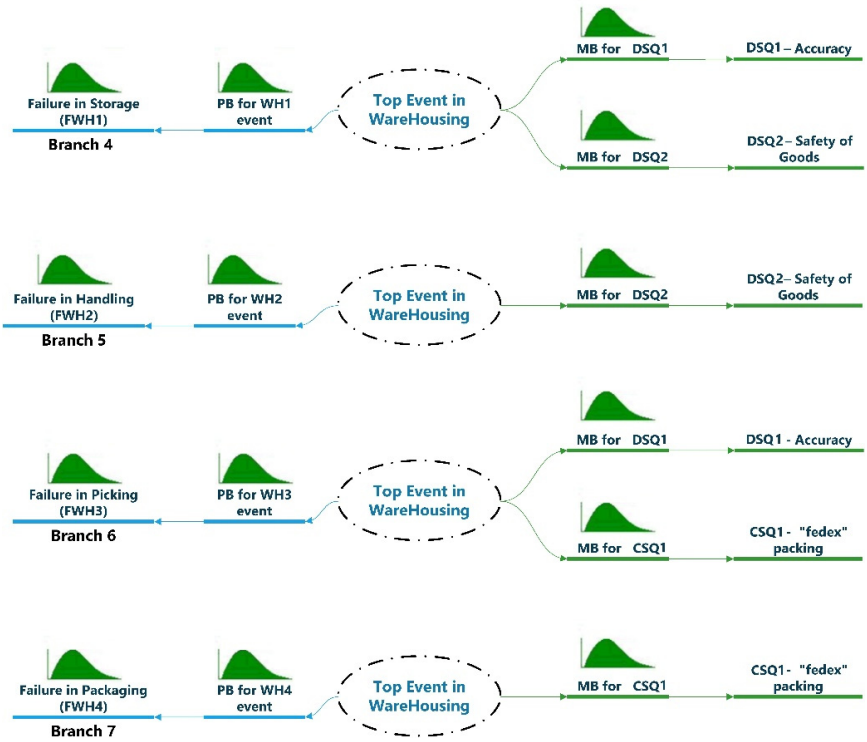

Figure 8. Bowtie diagrams for the warehousing category. *PB* stands for preventive barrier, and *MB* stands for mitigation barrier.

Figure 9. Bowtie diagrams for the transport category. *PB* stands for preventive barrier, and *MB* stands for mitigation barrier.

$$WH_{risk} = \begin{array}{c} P_{FWH1} \cdot P_{PB\_WH1} \cdot \left(P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_DSQ2} \cdot I_{DSQ2\_score}\right) \\ + \\ P_{FWH2} \cdot P_{PB\_WH2} \cdot P_{MB\_DSQ2} \cdot I_{DSQ2\_score} \\ + \\ P_{FWH3} \cdot P_{PB\_WH3} \cdot \left(P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_CSQ1} \cdot I_{CSQ1\_score}\right) \\ + \\ P_{FWH4} \cdot P_{PB\_WH4} \cdot P_{MB\_CSQ1} \cdot I_{CSQ1\_score} \end{array} \quad (2)$$

Figure 9 shows the bowtie schematically when referring to the transport category, and Equation (3) represents the aggregate risk of this category. Similar to the previous two categories, this equation is composed of three aggregate risk components: the first for loading logistics, the second for transportation, and the third for delivery. The aggregate risk of this category is the sum of these three components.

$$T_{risk} = \begin{array}{c} P_{FT1} \cdot P_{PB\_T1} \cdot \left(P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_DSQ2} \cdot I_{DSQ2\_score}\right) \\ + \\ P_{FT2} \cdot P_{PB\_T2} \cdot P_{MB\_DSQ3} \cdot I_{DSQ3\_score} \\ + \\ P_{FT3} \cdot P_{PB\_T3} \cdot P_{MB\_DSQ2} \cdot I_{DSQ2\_score} \end{array} \quad (3)$$

The terms used in Expressions 1 through 3 are a combination of the terms listed in Table 1 and the terms "PB" and "MB", which stand for preventive barrier and mitigating barrier, respectively. The combination of these terms can be found in Figures 7–9. These combinations of terms are presented in Equations (1)–(3) for two situations: first, to indicate the probability of failure of a particular logistics operation, and second, to indicate the impact defined in Table 2. For example, P_{FOP2} represents the failure probability of "(2) Order Management" (see Table 1), P_{PB_OP2} represents the failure probability of the preventive barriers of "(2) Order Management", and I_{SQ2_score} represents the corresponding impact specified in Table 2 for "(2) Consumer Information Security".

After evaluating the aggregate risk of logistics operations according to each category, it is possible to evaluate the reputational risk of the company providing logistics services using Equation (4). Here, the reputational risk is the sum of the aggregated risks for the categories of order processing, warehousing, and transportation.

$$Risk_{reputation} = OP_{risk} + WH_{risk} + T_{risk} \quad (4)$$

3.2.6. Framework Step 6—Prioritization according to Reputational Risk Using the Monte Carlo Method

The previous steps presented the proposed framework for assessing reputational risk based on customer satisfaction factors and logistics operations. For each of the operations, the overall risk was determined by the probabilities of failure for each logistics operation, so the reputational risk evaluated by Equation (4) is highly dependent on these probabilities.

In practice, however, these probabilities may vary depending on the assumptions used to evaluate these same probabilities. To account for these variations when assessing reputational risk, the failure probabilities of the logistics operations and the prevention and mitigation barriers are represented by their expected value (average value, μ) and their respective variance (σ).

To evaluate the reputational risk taking into account this variance, the Monte Carlo method is used. In this method, the failure probabilities of the individual logistics operations fluctuate randomly around their mean value, which corresponds to the effect of the respective variance in each simulation. In this sense, to evaluate reputational risk, a large number of simulations are performed for Equation (4) to obtain the average value of the reputational risk and the corresponding variance. This result is later used to prioritize companies according to their reputational risk. This prioritization is performed by pairwise comparison, considering the probability that the average value of reputational risk for one company is higher than the average value for the other company. After this comparison is made between all the companies, the company with the lowest probability is selected because it is the company with the lowest reputational risk.

4. Illustrative Case Study, Results and Discussion

To illustrate the applicability of the proposed model, the case study of three freight transportation companies, Companies A, B, and C, operating within a collaborative logistics network was considered. The purpose of this case study is to evaluate the reputational risk

of each of these three companies and prioritize them according to this risk. The company with the lowest risk in terms of customer satisfaction is selected as a candidate for the logistics mission under study. In practice, this prioritization is taken into account when selecting the company, along with other selection parameters such as the cost and time required for the logistics operation.

The first step in applying the model is to evaluate the probabilities of failure in each company's logistical processes. The initial values of these probabilities are obtained through questionnaires given to the company by using fuzzy logic frameworks and are later updated through satisfaction surveys of the collaborative network's customers. Table 3 shows the failure probabilities for the three companies according to the logistical processes already identified. It also shows the failure probabilities of the prevention barriers that each company has in each logistical process. These results are the first public results from the companies' surveys. The value μ represents the average probability of failure and the standard deviation σ represents the variance of this probability, which is used to account for the uncertainty about the assumptions used to evaluate the average value of the probability.

Table 4 shows the probability of failure of the barriers designed to mitigate or eliminate negative impacts on the elements indicated in the first column of Table 4. Similar to the determination of the data in Table 3, these values come from questionnaires sent to companies and must then be updated using satisfaction surveys of the customers of the cooperation network.

Table 3. Mean and standard deviation of failure probabilities in logistics operations and prevention barriers.

	Company A				**Company B**				**Company C**			
	Normal Distribution for Failures in Logistic Processes		**Normal Distribution for Failures in Preventive Barriers**		**Normal Distribution for Failures in Logistic Processes**		**Normal Distribution for Failures in Preventive Barriers**		**Normal Distribution for Failures in Logistic Processes**		**Normal Distribution for Failures in Preventive Barriers**	
	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ
(1) Order Processing	0.4	0.1	0.3	0.1	0.3	0.2	0.4	0.2	0.2	0.1	0.6	0.1
(2) Order Management	0.3	0.1	0.4	0.15	0.35	0.1	0.4	0.15	0.3	0.1	0.2	0.1
(3) Post processing	0.42	0.2	0.2	0.1	0.4	0.2	0.3	0.1	0.5	0.1	0.6	0.1
(1) Storage	0.3	0.2	0.4	0.2	0.3	0.1	0.5	0.2	0.2	0.1	0.4	0.1
(2) Handling	0.4	0.15	0.5	0.1	0.35	0.15	0.6	0.2	0.6	0.1	0.5	0.1
(3) Picking	0.35	0.1	0.4	0.2	0.6	0.1	0.3	0.2	0.4	0.2	0.5	0.2
(4) Packaging	0.4	0.2	0.4	0.1	0.4	0.2	0.4	0.2	0.3	0.1	0.4	0.1
(1) Loading	0.6	0.2	0.6	0.1	0.3	0.14	0.5	0.1	0.4	0.2	0.5	0.2
(2) Transport	0.4	0.2	0.3	0.1	0.5	0.2	0.2	0.1	0.5	0.1	0.4	0.1
(3) Delivery	0.2	0.1	0.5	0.2	0.3	0.1	0.3	0.1	0.3	0.1	0.5	0.1

Table 4. Mean and standard deviation of failure probabilities of mitigation barriers.

	Company A		**Company B**		**Company C**	
	Normal Distribution for Failures in Mitigation Barriers		**Normal Distribution for Failures in Mitigation Barriers**		**Normal Distribution for Failures in Mitigation Barriers**	
	μ	σ	μ	σ	μ	σ
(1) Information Transparency	0.2	0.1	0.5	0.1	0.6	0.2
(2) Consumer information security	0.3	0.2	0.6	0.1	0.3	0.1
(3) Logistics and customs information level	0.4	0.1	0.3	0.1	0.3	0.1
(1) Accuracy	0.5	0.1	0.3	0.1	0.5	0.1
(2) Safety of Goods	0.3	0.1	0.3	0.1	0.3	0.1
(3) On-Time Deliveries	0.5	0.1	0.4	0.1	0.3	0.1
(1) "fedex" packing	0.3	0.1	0.3	0.1	0.5	0.1
(2) Error handling	0.2	0.1	0.4	0.2	0.3	0.1
(3)Value-Added Services	0.5	0.1	0.5	0.1	0.3	0.1
(1) International logistics services	0.3	0.1	0.6	0.1	0.5	0.1
(2) Policy and regulatory level	0.2	0.1	0.5	0.1	0.3	0.2

The next step is the application of the Monte Carlo method. The objective is to evaluate the reputational risk represented by Equation (4), taking into account the variation of the probabilities presented in Tables 3 and 4. These probabilities may vary according to the operational uncertainties that logistics companies face in their operations. With this in

mind, the variance of each mean value in Tables 3 and 4 is intended to account for the impact of this uncertainty when evaluating the probability of failure.

Tables 5 and 6 show the failure probabilities calculated in simulation number 10,000 of the Monte Carlo model implemented for this case study. In each simulation, the probabilities are evaluated for each element listed in the first column of Tables 3 and 4. These probabilities are calculated using the mean values given in Tables 3 and 4 and taking into account a random parameter that is used together with the variance to update the mean value in each simulation.

For each Monte Carlo simulation, the risk of each branch shown in Figures 6–8 is evaluated using Equations (1)–(3), where the first term of Equation (1) represents the risk of Branch 1, the second term represents the risk of Branch 2, and the third term represents the risk of Branch 3. This reasoning also applies to the other two equations if we continue the numbering of the branches up to branch number 10.

Table 7 shows the results for the risks calculated in Monte Carlo simulation number 10,000 for branches 1 to 10. The last row of Table 7 shows the reputational risk assessed for each company. This risk is evaluated using Equations (1)–(4).

The reputational risk assessed in each Monte Carlo simulation for each of the three companies is shown in Table 8. The mean value of each company's reputational risk and its respective variance are determined by the respective values in each column of Table 8.

Table 9 shows the mean values and respective variance of reputational risk obtained using the data presented in Table 8.

It can be seen from Table 9 that the reputational risk of Company A is lower than the risk calculated for companies B and C. The risk value calculated for Company A is 2.731 compared to 2.897 and 3.238 for Company B and C, respectively. Based on these values, it can be concluded in an initial analysis that Company A is the candidate that should be selected.

However, the variance around the average value of reputational risk for these two companies (B and C) is high, 0.806 and 0.755, so the reputational risk for these two companies might be lower compared to company A. Based on these results, it seems necessary to calculate the probability that the risk of Company A is greater than the risk of the other two companies. Taking into account the mean values and the respective variance, Table 10 shows the probabilities for the results obtained for each company as presented in Table 9.

This table is intended to show a comparison between the probability that the reputational risk of the company indicated vertically is greater than the reputational risk of the company indicated in the horizontally. In this sense, in the first row, we have P (risk_reputation_A > risk_reputation_B) = 0.396 and P (risk_reputation_A > risk_ reputation_C) = 0.209. In the second row, we have P (risk_reputation_B > risk_reputation_A) = 0.581 and P (risk_reputation_B > risk_reputation_C) = 0.336, and in the third row, we have P (risk_reputation_C > risk_reputation_A) = 0.749 and P (risk_reputation_C > risk_ reputation_B) = 0.674.

From these results and by inspection, it can be concluded that the probability of reputational risk for Company A is lower than the probability of reputational risk for Company B and Company C. It can also be concluded that the probability of reputational risk for Company C is higher than that for Company B. According to this logic, companies can be prioritized by the probability of aggregate reputational risk, calculated as follows:

$$\begin{aligned} &\text{Aggregate\_Risk\_A} = \text{P (Reputation\_Risk\_A} > \text{Reputation\_Risk\_B)} \times \text{P (Reputation\_Risk\_A} > \text{Reputation\_Risk\_C)} = 0.083 \\ &\text{Aggregate\_Risk\_B} = \text{P (Reputation\_Risk\_B} > \text{Reputation\_Risk\_A)} \times \text{P (Reputation\_Risk\_B} > \text{Reputation\_Risk\_C)} = 0.195 \\ &\text{Aggregate\_Risk\_C} = \text{P (Reputation\_Risk\_C} > \text{Reputation\_Risk\_A)} \times \text{P (Reputation\_Risk\_C} > \text{Reputation\_Risk\_B)} = 0.505 \end{aligned} \quad (5)$$

Table 5. Failure probabilities of logistics processes and preventive barriers evaluated in simulation number 10,000 of the implemented Monte Carlo method.

	Company A				**Company B**				**Company C**			
	Probability of Failure in Logistic Processes		**Probability of Failure in Preventive Barriers**		**Probability of Failure in Logistic Processes**		**Probability of Failure in Preventive Barriers**		**Probability of Failure in Logistic Processes**		**Probability of Failure in Preventive Barriers**	
	Pf	**Random**	**Pf**	**Random**	**Pf**	**Random**	**Pf**	**Random**	**Pf**	**Random**	**Pf**	**Random**
(1) Order Processing (*OP1*)	0.344615668	0.29	0.376417265	0.78	0.0644844	0.12	0.3581813	0.42	0.2513171	0.70	0.7276357	0.90
(2) Order Management (*OP2*)	0.155990711	0.07	0.611259392	0.92	0.2041962	0.07	0.2845117	0.22	0.2575618	0.34	0.0995741	0.16
(3) Post processing (*OP3*)	0.043098423	0.03	0.235639856	0.64	0.1491934	0.10	0.1062841	0.03	0.4325563	0.25	0.5369719	0.26
(1) Storage (*WH1*)	0.308614987	0.52	0.523594187	0.73	0.146234	0.06	0.678595	0.81	0.2556922	0.71	0.4618898	0.73
(2) Handling (*WH2*)	0.277570231	0.21	0.33906198	0.05	0.2418399	0.24	0.479767	0.27	0.7000912	0.84	0.4793787	0.42
(3) Picking (*WH3*)	0.330215016	0.42	0.545198633	0.77	0.6208444	0.58	0.1370531	0.21	0.4516185	0.60	0.3902767	0.29
(4) Packaging (*WH4*)	0.280228629	0.27	0.363893422	0.36	0.2558729	0.24	0.0325492	0.03	0.1950374	0.15	0.4144188	0.56
(1) Loading (*T1*)	0.482233116	0.28	0.655091886	0.71	0.4125167	0.79	0.4552511	0.33	0.6399273	0.88	0.4378567	0.38
(2) Transport (*T2*)	0.147400959	0.10	0.46014014	0.95	0.2941457	0.15	0.3755107	0.96	0.5399146	0.66	0.3574589	0.34
(3) Delivery (*T3*)	0.300766436	0.84	0.635721378	0.75	0.2067216	0.18	0.4002937	0.84	0.2415594	0.28	0.614	0.87

Table 6. Failure probabilities of mitigation barriers evaluated in simulation number 10,000 of the implemented Monte Carlo method.

		Company A		Company B		Company C	
	Inpact Score	Normal Distribution for Failures in Mitigation Barriers		Normal Distribution for Failures in Mitigation Barriers		Normal Distribution for Failures in Mitigation Barriers	
		Pf	Random	Pf	Random	Pf	Random
(1) Information Transparency (SQ1)	2	0.228613	0.6126106	0.688431	0.9702385	0.6303423	0.5602928
(2) Consumer information security (SQ2)	3	0.3831018	0.6611153	0.4563995	0.0755004	0.2808925	0.4242333
(3) Logistics and customs information level (SQ3)	1	0.4917024	0.8204349	0.1591936	0.0795561	0.3880568	0.8107242
(1) Accuracy (DSQ1)	2	0.4987228	0.4949049	0.1842884	0.1236124	0.454455	0.3243929
(2) Safety of Goods (DSQ2)	3	0.3695459	0.756616	0.2839819	0.4363692	0.2738498	0.3968528
(3) On-Time Deliveries (DSQ3)	3	0.4542841	0.3237782	0.5387168	0.9173047	0.2529378	0.3189553
(1) "fedex" packing (CSQ1)	2	0.1013981	0.0235156	0.3713046	0.7620915	0.4327609	0.2506675
(2) Error handling (CSQ2)	3	0.2201374	0.579797	0.6609285	0.9039927	0.1736329	0.103174
(3) Value-Added Services (CSQ3)	1	0.5060156	0.5239842	0.4262457	0.2303961	0.2811505	0.4252444
(1) International logistics services (CBSQ1)	3	0.1974268	0.1525089	0.8290865	0.9890144	0.5854613	0.8036172
(2) Policy and regulatory level (CBSQ2)	2	0.169929	0.3818179	0.514267	0.5567245	0.485701	0.8234272

Table 7. Risk for each branch and reputational risk calculated in Monte Carlo simulation number 10,000.

	Company A	Company B	Company C
Branch 1	0.18843846	0.653536678	0.010662227
Branch 2	0.417734047	0.365805778	0.356160204
Branch 3	0.319732967	1.768867134	1.471803733
Branch 4	0.079837547	0.125222829	0.14111562
Branch 5	0.232910332	0.076896356	0.394378903
Branch 6	0.116797202	0.244482525	0.090480277
Branch 7	0.02127848	0.043013081	0.105316925
Branch 8	0.659170289	0.156031371	0.949581896
Branch 9	0.229789095	0.295664854	0.144217832
Branch 10	0.190576907	0.149215438	0.131807603
Risk_reputation_score	2.456265326	3.878736044	3.795525221

Table 8. Reputational risk per iteration and by company analyzed.

Simulation Number	Company A Reputational Risk	Company A Reputational Risk	Company A Reputational Risk
1	3.376473996	2.314079177	3.277318329
2	1.815237859	2.860850945	5.003561491
3	3.965828692	2.980162893	3.820033112
~	~	~	~
5000	2.456200257	2.546652487	4.6678389
10,000	2.08032168	1.48050689	4.26413586
~	~	~	~
100,000	2.66873863	2.868919556	3.679251406

Table 9. Reputational risk results for companies A, B and C.

Company A Reputational Risk		Company B Reputational Risk		Company C Reputational Risk	
μ	σ	μ	σ	μ	σ
2.7310085	0.6270645	2.8964258	0.8052228	3.237577	0.7553293

Based on these results, it is confirmed that Company A has the lowest reputational risk, followed by Company B and finally Company C. This prioritization of companies according to their reputational risk in conjunction with other optimization parameters, namely, cost and time parameters, enables the selection of the transportation company that minimizes reputational risk and maximizes financial return.

Table 10. Relative probabilities of reputational risk between companies.

>	A	B	C
A	0	0.3959684	0.209591
B	0.5813821	0	0.3359021
C	0.7487812	0.6742426	0

In this way, the sustainability of collaborative networks in the field of logistics should be promoted by creating trust among both collaborators and customers. This trust will also encourage the participation of new collaborators, as the collaborative approach has not attracted the desired number of collaborators due to the lack of trust in this type of approach. Attracting new collaborators and the continued participation of the current collaborators in the collaborative network are two fundamental factors for the growth of the network. This growth is extremely important to promote the sustainability of collaborative networks as well as their efficiency and optimization. On the other hand, the presence of a quality indicator such as reputational risk, as proposed in this study, will motivate companies to develop and implement quality programs to reduce reputational risk and, in this way, will increase their participation in collaborative network activities and, consequently, their revenue share.

The research limitations of this study are mainly related to the data acquisition approach used in the illustrative case study, i.e., to obtain the primary data used in the proposed model, it is necessary to apply a structured approach to capture the probabilities of failure along with their respective variance, which was not performed in this research as it has been reserved for future work. In addition to supporting decision making, it is also envisioned that the synergy of the proposed model with other supply chain models [48–51] can extend the applicability of the proposed model not only to partner selection, but also to supplier selection.

5. Managerial Insights

The implementation of the proposed model will make it possible to define a series of measures to evaluate the quality of the services provided by each company in the network. In this sense, it will be possible to identify points for continuous improvement. It will also strengthen the trust between suppliers, customers, and the collaborative network. It will also encourage the participation of new collaborators in the network, increasing the size of the collaborative network, which in turn will promote its sustainability. Logistics companies can thus lower their operating costs by reducing waste and increase customer satisfaction through shorter delivery times, which in turn strengthens the business relationship between customers and suppliers.

6. Conclusions

In this paper, a new methodology has been developed to support decision making when selecting operators in a collaborative network for the provision of logistics services. This methodology is based on a new reputational risk assessment model developed in this paper, which, together with cost and time parameters, allows the selection of the most suitable logistics service provider for a given logistics contract. The developed reputational risk model takes into account the expectations of customers demanding logistics services and the potential risk factors associated with the activities of logistics companies.

In addition to the prioritization of logistics companies, the proposed model of reputational risk also allows the creation of a quality index related to the services provided by logistics companies in the collaborative network. It allows the evaluation of the quality level of each operator in the most important areas and with regard to the impact on the customers of the collaborative network. This assessment is an important point of feedback that logistics companies can use to improve the quality assessment of their logistics operations by implementing quality programs.

Along with the above benefits, the collaborative network also benefits from the implementation of the proposed reputational risk model by increasing the trust of its customers and logistics service providers. The increase in trust promotes the continuity of the companies that are already part of the collaborative network and the participation of new companies, thus promoting the sustainability of the network. On the other hand, the sustainability of the network promotes the reduction of the sector's environmental footprint, which is in line with the goals of the UN Agenda 2030.

As for future work, we propose to integrate the developed model into the multicriteria decision making models commonly used in collaborative logistics networks. We also propose the development of a framework to evaluate the level of satisfaction of the end customers with the logistics service providers to update the failure probabilities after each logistics mission. It is also planned to correlate the proposed model with other models in real case studies to identify operational problems, to and develop a structured approach to evaluate the failure probabilities in each logistics operation considered in the proposed model.

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Identifying Project Corporate Behavioral Risks to Support Long-Term Sustainable Cooperative Partnerships

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Abstract: Projects are considered crucial building blocks whereby organizations execute and implement their short-, mid-, and long-term strategic visions. Projects are thought, developed, and implemented to solve problems, drive change, satisfy unique needs, add value, and exploit opportunities, just to name a few objectives. Although existing project management tools and techniques aim to deliver projects with success, according to the latest reviewed literature, projects still keep failing at an impressive pace. Among the extensive list of factors that may threaten project success, several articles from the research literature place particular importance on a still underexplored factor that may strongly lead to unsuccessful project delivery. This factor—usually known as corporate behavioral risks—usually emerges and evolves as organizations work together to deliver projects across a bounded period of time, and is characterized by the mix of formal and informal dynamic interactions between the different stakeholders that constitute the different organizations. Furthermore, several articles from the research literature also point out the lack of proper models to efficiently manage corporate behavioral risks as one of the major factors that may lead to projects failing. To efficiently identify and measure how such corporate behaviors may contribute to a project's outcomes (success or failure), a heuristic model is proposed in this work, developed based on four fundamental fields ((1) project management, (2) risk management, (3) corporate behavior, and (4) social network analysis), to quantitatively analyze four critical project social networks ((1) communication, (2) problem-solving, (3) advice, and (4) trust), by applying the theory of social network analysis (SNA). The proposed model in this work is supported with a case study to illustrate its implementation and application across a project lifecycle, and how organizations can benefit from its application.

Keywords: project risks; corporate behavior; social network analysis; project management; risk management; project critical success factors; sustainable cooperative partnerships

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1. Introduction

Projects have been around since humans have inhabited the planet earth [1]; consequently, project management has as well [1]. Although there is very little documentation regarding how projects such as the Great Wall of China, the Great Pyramid of Giza, the Coliseum, or the Hanging Gardens of Babylon—just to name a few—have been managed, after the mid-1950s organizations began to apply systematic tools and techniques to manage complex projects [1].

A project can be defined as a temporary endeavor undertaken to create a unique product, result, or service, and it is usually managed by the project management standards scientific field, which can be defined as a set of tools, techniques, skills, and knowledge that are applied to project tasks and activities to meet project requirements across the different phases of a given project lifecycle [1–4].

Some authors argue that from the 1900s initiated the so-called modern project management era, which is essentially characterized by the introduction of innovative tools and techniques such as Gant Charts, the Critical Path Method, the PERT technique, the PRINCE model, the CCPM model, the PMBOK book of knowledge, and the Agile methodologies—just to name a few—to efficiently plan and execute projects [1–4]. For example, the Gant Charts—developed by Henry Gant (1861–1919)—are used to break large projects into smaller manageable activities and tasks and explicitly illustrate the dependency of some tasks on each other across a project lifecycle [2,4]. The Critical Path Method (also known as CPM)—developed by the E.I du Pont de Nemours Company in the 1950s— is used to accurately estimate the cost and time of a project. The Program Evaluation Review Technique (also known as PERT)—developed by the US Navy in the 1950s—is used to visualize the different scheduling scenarios of a project. The Projects in Controlled Environments method (also known as PRINCE)—developed by the UK Government in the late 1980s—is used to manage information systems projects. The Critical Chain Project Management method (also known as the CCPM method)—developed by Israelis Eliyahu M. Goldrat in the 1990s—is used as an alternative to the PRINCE method. The Project Management Body of Knowledge (also known as PMBOK)—developed by the Project Management Institute (PMI) in the late 1990s—is used to manage physical projects of all sizes and complexities. The Agile manifesto—developed by software developers in USA in the late 1990s—is used as an alternative to one of the most used methods of managing physical and software projects, the waterfall method (also known as the stage gate model), to better meet changing project needs.

Despite the large number of existing methods, methodologies, tools, and techniques developed to manage projects, according to the latest research [5–9], projects still keep failing at an impressive rate. According to the latest research, only about 29% of all delivered projects were delivered successfully [7,8]. Among the multiple factors that potentially threaten the successful delivery of a project—such as poor communication, inaccurate project requirements, unskilled project team, lack or inexistence of effective stakeholder management, just to name a few—one factor has been arousing particular interest among the project management scientific community's researchers and practitioners. This factor concerns the different project stakeholders' dynamic interactions (also known as dynamic behaviors [10]) that emerge and evolve across the different phases of a project lifecycle, and the impact that such dynamic interactions—characterized by a mix of formal and informal relationships—may have on a project's outcome [6,10–12]. In fact, several studies argue that more important than individual competencies, training, and skills is the way that the different project stakeholders collaborate (dynamically interact within the mix of formal and informal relationships) across a project lifecycle, which dictates how successful or unsuccessful a project will be [13–15].

Although several studies show that it is not very clear to distinguish formal from informal organizational networks of relationships [16,17], if they are not identified in a timely way and efficiently managed (particularly the informal organizational networks), they may either evolve to two different collaborative extremes: (1) a collaborative overload status, or (2) a lacking or nonexistent collaborative status [18]. Whichever the extreme they evolve to (either (1) or (2), as mentioned before), such organizational networks of relationships may strongly threaten or boost the successful delivery of a project, being thus characterized as project corporate behavioral risks. According to [12], project corporate risks can be delayered into four different types. These are: (1) critical enterprise risks (risks associated with project stakeholders who have exclusive competencies, know-how, or resources), (2) resource allocation risks (risks associated with the distribution of project tasks and activities throughout the different project stakeholders), (3) managerial risks (risks related to the authority, structure, and level of communication within the project stakeholder collaborative network), and finally (4) behavioral risks (risks that derive from the mix of myriad formal and informal dynamic interactions between different project stakeholders, across the different phases of a project lifecycle).

Understanding the extent to which corporate behavioral risks influence a project's outcomes is of high importance for organizations and society in general, and can be explained in two dimensions. (1) It is a driver of sustainable business because it enables organizations that deliver projects (among other things) to increase the chances of project success, by enabling the development and implementation of effective, appropriate, and timely corrective/supportive measures for a project's tasks and activities. (2) It generates unique, valuable, and actionable knowledge regarding the emergence and evolution of cooperative risks, contributing thus to the scientific community in the organizational field, to society in general, and to the development of new theories and approaches for how to efficiently and properly manage behavioral project risks across a project lifecycle [10,14,19].

Research in sociology and project management shows that the only effective way to understand how such dynamic interactions between the different stakeholders across a period emerge, evolve, and eventually continue or disappear is by the application of social network analysis (SNA) tools and techniques [10,14,20–22]. The reason behind this is that contrary to traditional project management tools and techniques, SNA provides the adequate theoretical frameworks for modeling dynamic social interactions, where entities (persons, groups, organizations, and so on) are transformed into nodes or points, and the different relationships between them are represented by lines, or links, which can be quantitatively measured by analyzing their direction (preferences) and weights (intensities) [10,14,20–22].

In a nutshell, the objective of this work is to present a heuristic model that efficiently identifies and correlates corporate behavioral risks to support long-term sustainable cooperative partnerships by analyzing and quantitatively measuring the different dynamic interactions between the different project stakeholders contained in a set of interactional networks, such as communication, problem-solving, advice, and trust, that usually emerge and evolve across the different phases of a project lifecycle, by applying SNA centrality metrics. The proposed model in this work results from the combination of four scientific fields ((1) project management, (2) risk management, (3) corporate behavior, and (4) social network analysis), which in a holistic way provides the model with a novelty and uniqueness to its approach in identifying corporate behavioral risks (also known as critical project social networks).

Essentially, the combination consists of the harmonization of the individual contributions of each of the scientific fields in one block (the model), providing three main benefits for organizations: (1) it efficiently enables an effective implementation and adaptation of the proposed model in projects environments, causing the least disturbance (contributions of the project management field); (2) it accurately captures unique dynamic interactive behaviors that flow in some interactive social channels (contributions of the cooperative behavior field); and (3) it efficiently, quantitatively measures and pragmatically analyzes results according to best practices and worldwide accepted standards (contributions of social network analysis theory and risk management fields), especially when correlating them with a project's outcomes (success or failure).

Structure of This Work

The present work is divided into five chapters. In Section 1, we introduce the main scientific fields and their individual contributions, as well the motivation that led to the development of the proposal in this work. In Section 2, an extensive literature review is presented on the main scientific fundamental fields ((1) project management, (2) risk management, (3) corporate behavior, and (4) social network analysis) that support the development of the proposed model. In Section 3, the development of the proposed model is explained, as well as the implementation steps in an organizational context. In Section 4, a case study is presented regarding the implementation and application of the proposed model, covering the complete analysis process that goes from data collection and analysis, to the interpretation of results. Finally, in Section 5, the implications of the proposed model regarding managerial and research dimensions are discussed, covering subjects such as

benefits, limitations, and further research regarding the proposed model in the context of organizational project management.

2. Literature Review

2.1. Project Management

According to the PMI (Project Management Institute) [4], a project is defined as a temporary endeavor with a defined start and end, which aims at the creation of a unique result, product, or service. In order to increase the chances of delivery, successful project management tools and techniques are applied to projects tasks and activities. The PMI defines project management as the application of knowledge and techniques to project activities throughout the different phases of a project lifecycle, aiming at the successful delivery of a project within a project's constraints [4]. Project management methods, tools, and techniques, such as those already mentioned in the introduction (the Gant Charts, the Critical Path Method, the PERT technique, the PRINCE model, the CCPM model, the PMBOK book of knowledge, the Agile methodology), are applied throughout the different phases of a project's lifecycle to, in a timely manner, identify and manage project risks, so that projects can be delivered with success [4,5]. However, according to the Standish Group [8], over the last 20 years, it seems that such project management methods, tools, and techniques have done little or nothing to improve project success. A survey conducted by the Standish Group regarding private and public projects shows that only 29% of all projects delivered were delivered successfully. Such results are supported by the PMI's Pulse report of the project management profession [9], where it shows that on average more than 50% of delivered projects experienced some type of scope creep—which means a continuous or uncontrolled growth in a project's scope that it is different from the plan. Still, according to The Standish Group [8], the four main reasons that lead to project failure are: (1) low or lack of end-user involvement and input, (2) low or lack of executive management support, (3) unclear statement of requirements, and (4) uncontrolled change requirements and specifications.

In addition, other researchers still point out organizational culture, inadequately trained and/or inexperienced project managers, lack of project governance, inadequate tools and methods, poor requirements management, poor planning and estimating, inadequate communication and reporting, poor risk management, and misalignment between projects and organizational strategy, as being factors responsible for project failure [22,23].

According to David Hillson [11], a renowned risk and project management author and researcher, the results published in the Standish Group and PMI's reports are no surprise. Hillson [11] suggests three major project areas where further research should be undertaken to improve project success. These are (1) processes (project risk management approaches and standards still must be improved), (2) principles (the definition of risk in the project environments is still very subjective), and (3) people (people's culture, know-how, skills, interactions, and roles are different from person to person and have different impacts in how project tasks and activities are executed).

Similarly to other researchers in the field of project management [10,14,15], Hillson [11] highlights the importance of the people aspect in project management. The reason behind this is that there are no two persons alike, and cultural differences seem to directly influence how risk is perceived and understood, which in turn, creates different behaviors towards risk management in project environments, among other things.

In this line of thought, the proposed model in this work is in line with the latest research in the project management field, which place particular importance on understanding the extent to which different human behaviors contribute to the failure or success of projects, by analyzing how the different project stakeholders' dynamic behaviors emerge and evolve across the different phases of a project lifecycle, and how these may be correlated with project success or failure.

2.2. Risk Management

Risk management can be defined as a set of coordinated activities to direct and control an organization regarding risk [4,24]. It is a combined and continuous process that includes analysis, decision-making, and proactive management across the different tangible and intangible parts of an organization, such as design and structure, strategy, operations, culture, and governance, respectively, where instead of being policed by experts internal or external to the organization, it should be supported and incentivized [25,26].

One of the most popular processes to support risk management activities is the ISO 31000:2018—Risk management—Guideline's standard, published by the ISO (the International Organization for Standardization) [24]. The reason for its popularity is due to its ability to be implemented in almost any scenario, regardless of an organization's type, objective, or size [24].

The risk management process defined in the 31000:2018 standard [24] is essentially described in six interrelated steps. They are: (1) establishing scope context and criteria (consists in defining the scope of the risk management activities, including the internal and external context, and the amount and type of risk that a particular organization is willing to take, relative to their objectives), (2) risk identification (comprises the activities of finding, recognizing, and describing risks that might contribute to or hinder an organization achieving its objectives), (3) risk analysis (consists in understanding the nature of a particular risk in different dimensions, such as uncertainties, risk sources, consequences, likelihood, events, scenarios, and controls and their effectiveness), (4) risk evaluation (consists in comparing the results of the risk analysis with the previously established organizational risk criteria to identify where additional action is required), (5) risk treatment (consists in the specification of how to choose treatment options to be implemented), and finally (6) record and report previous steps (comprises the continuously monitoring and reviewing of identified risks evolution across time, and the efficacy of applied control or corrective measures).

Although the word risk is immediately connotated with some kind threat, risk comprises two dimensions [4]. First, risk can be a threat that, if it occurs, will negatively impact organizational goals and objectives. Second, risk can be an opportunity that, if it occurs, will positively impact organizational goals and objectives. Research in the field of project risk management [11,27] simply defines project risks as the uncertainty that matters. This simple but efficient definition aims to develop a certain mindset that stresses that it is critical to separate real project risks from unreal project risks. To better understand and classify the different project risk types, Hillson [27] proposes four generic types of project risks. They are (1) event risks, (2) variability risks, (3) ambiguity risks, and (4) emergent risks, and are illustrated and explained in Table 1.

Table 1. Four generic project risk types.

Project Risk Types	What They Mean	How to Manage Them
(1) Event Risk	Risks related to something that has not yet happened, and it may indeed not happen at all, but if it does, it will surely impact project objectives.	Tools and techniques for identifying, assessing, treating, and monitoring risks, supported by well-known risk management standards and best practices.
(2) Variability Risk	Risk characterized by a given number of possible known outcomes; however, no one knows exactly which one will take place.	Advanced risk analysis models such as the Monte Carlo simulation.
(3) Ambiguity Risk	Risks that arise from lack of knowledge (know-how and know-what). They may include use of the latest project technology, and market and competitor capability or intentions, among other things.	Lessons learned, prototyping, and simulating techniques.
(4) Emergent Risk	Risk that are just unable to be seen or predicted, because they are outside a person's mindset, and usually arise from game-changers and paradigm-shifters, such as disruptive inventions.	Efficient contingency planning.

As is illustrated in Table 1, project risks can be divided into four major types where for each type, a management process is also suggested. The overall functioning principle of the proposed model in this work is inspired by the risk management process steps defined in the ISO 31000:2018; the equivalent process steps are illustrated in Table 2.

Table 2. Proposed model functioning process.

Risk Management Steps According to the ISO 31000:2018 Standard [24]	Proposed Model Process Equivalent Steps
Step 1: establish scope, context, and criteria	Define scope (project stakeholders' behaviors across a project lifecycle) and establish information collection process (mails, surveys, etc.) to map the four critical project social networks (communication, problem-solving, advice, and trust).
Step 2: risk identification	Apply SNA centrality metrics to collected data, to quantitatively measure different behavioral patterns from project stakeholders.
Step 3: risk analysis	Analyze the results and correlate them with project evolution and desired or established collaborative patterns.
Step 4: risk evaluation	Evaluate the impact of identified collaborative behaviors in project outputs and outcomes in two dimensions—threats and opportunities.
Step 5: risk treatment	Define and implement strategies to support, correct, or adjust identified behavioral patterns.
Step 6: monitoring, & reviewing	Continuously monitor implemented supportive or corrective measures, in order to access their effectiveness and record lessons learned.

As can be seen in Table 2, the proposed model in this work frames the ISO standard 31000:2018—Risk management—Guidelines standard steps throughout the identification and analysis process of project corporate behavioral risks. Simultaneously, the proposed model in this work particularly addresses the ambiguity project risk type illustrated in Table 1. This happens because the model identifies hidden behaviors in a quantitative way regarding the dynamic interactions of project stakeholders across a project lifecycle, contributing to the generation of knowledge (lessons learned) concerning which factors are more or less important to drive a project to success.

2.3. Corporate Behavior

Corporate behavior can be defined as the set of actions of an organization or group that defines the organization's ethical strategies and simultaneously describes the external and internal image of an organization [28]. Such actions essentially define the way an organization behaves within the environment where it exists, in both internal (characterized by internal processes and procedures) and external (characterized by collaboration with other organizations) environments [28]. Research shows that there is interdependence between three essential concepts that explain how behavior emerges and is adopted as normal [5,6,11]. Such interdependence is explained by the ABC model (attitude, behavior, culture), also known as the ABC of risk culture [11]. In a nutshell, the ABC model states that, first, attitude shapes behavior; second, repeated behavior forms culture; and third, culture influences attitude and behaviors. In this line of thought, it can be concluded that neither attitudes nor behaviors are static. They rather depend on culture's influence, which is also not static. This suggests that it is possible to act in one of the three mentioned dimensions (attitudes, behavior, or culture) to influence the other two.

According to research, in organizations, as a function of their dynamic interactions as they operate in the internal and external environments, behavioral risks (also known as collaborative risks) are likely to emerge [6,12]. Research suggests the classification of organizational collaborative risks into four distinct but interrelated dimensions [12]. The first dimension, called critical enterprise risks, covers risks that are associated with project social network members who have exclusive resources or competencies or are assigned to tasks or activities of great complexity. It regards various aspects, such as what may happen to collaborative performance if a particular partner is removed from

a project social network of an ongoing project. The second dimension, called resource allocation risks, covers risks that result from how tasks and project activities are distributed across the different organizations that work together to deliver projects. It comprises aspects, such as access to resources (knowledge, technologies, social capital, and so on), that enable organizations to perform assigned project tasks or activities, or how equally the workload is distributed across project partners. The third dimension, called managerial risks, are risks that are associated with authority and structure regarding communication in a collaborative network. It comprises the identification of how organizations can get help other partners to accomplish their project tasks and activities, and analysis of how balanced the communication of a given project social network is. Finally, the fourth dimension, called behavioral risks, are risks associated to the type of relationships that emerge, evolve, and eventually continue or disappear across time, between the different project stakeholders that work together to deliver projects. It consists in the identification of how collaboration (which involves communication, information exchange, and so on) evolves among the different project stakeholders, accessing various aspects, such as how project information is being shared, who turns to whom to get help and advice to perform project tasks or activities, who has expertise skills regarding a particular project task or activity, and so on. In addition to the ambiguity risk types, as previously mentioned in the risk management section, the proposed model in this work will address the above-mentioned behavioral risk dimension, also called cooperative behavioral risks.

2.4. Social Network Analysis

SNA can be defined as a process of studying and analyzing social structures, by the application of a variety of metrics developed based on graph theory, that contributes to the explanation of how social structures emerge, evolve, and eventually continue or disappear across time, and how they impact the environment where they exist [20]. SNA is continuously increasing in popularity in organizations, namely in the study of how dynamic interactions between entities across time may impact outputs and outcomes [20,29].

Furthermore, the application of SNA covers diverse scientific fields, such as management and leadership [30]; behavioral sciences [31]; law, criminology, and terrorism [32]; communication, learning and media [33]; and political science [34], just to name a few.

SNA is characterized by a set of specific linkages or connections among a defined set of actors or entities, where such linkages or connections are used to interpret social behavior of the involved entities or actors [35].

SNA efficiently addresses social capital challenges and has been integrated into traditional organizational risk management processes and frameworks, essentially to support decision making [10,36].

In organizations, SNA can be used to study employee retention and turnover, network collaboration levels, collective and individual performance, culture, innovation, social cohesion, information diffusion, values, ethics, behavior, wellness, satisfaction, fraud, and many other things [6,36].

In project management, the application of SNA—although still at a very initial stage according to some research [37]—is essentially used to identify project critical success factors by studying how the different project stakeholders' behaviors emerge and evolve across a given project lifecycle, and how such behaviors may impact project activities and outcomes [38,39]. In the last years, several researchers and authors have been showing how the application of SNA in project management can help organizations to be more efficient.

For example, Krackhardt and Hanson [40] identified three key informal networks that managers should be aware of to increase performance and project success. Such networks are still today considered by several research as being some of the most important informal networks to be analyzed, because they provide meaningful and actionable insight regarding how the different project stakeholders interact across a given project lifecycle [6,10,14,40]. They are: (1) advice network (identifies people to whom others go to get their job done, (2) trust network (identifies people who share project-related information

and with whom), and (3) communication network (identifies who talks to whom about project-related matters).

Mead [41] applied SNA to the analysis of different project teams to assess project communication evolution across time. Through this assessment, Mead identified a set of isolated project stakeholders, which enabled the development and implementation of an efficient corrective plan to better integrate those isolated project stakeholders in the project communication network.

Cross and Parker [42] applied SNA in diverse organizations, which led to the identification and characterization of a set of very popular informal actors' functions, in terms of their location within an organization's informal network, that strongly impact how work is done in organizations. They are: (1) central connectors (people who others heavily rely on for support and advice regarding work and personal matters), (2) boundary spanners (people who connect different organizations and groups), (3) information brokers (people that connect different functions within an organization), (4) peripheral experts (people that are subject matter experts), (5) peripheral intentionally (people that aren't well integrated in a project social network), and (6) energizers (people who energize others with positive energy).

Prell [43] applied SNA centrality metrics to identify and analyze project stakeholder networks in a natural resource management project. He used the results of SNA assessment to first select and then manage important project stakeholders.

Mok [44] applied SNA centrality metrics to identify critical challenges in major engineering projects (MEPs) based on interdependencies among critical stakeholders' concerns. The results of his assessment enabled the identification of several critical challenges that occurred in major engineering projects, which contributed to the development of a set of best project practices to properly manage future MEPs similar challenges.

Arena [15] applied SNA centrality metrics to develop a theory called adaptive space, which essentially argues that successful organizations efficiently connect two different critical areas—the operational and the entrepreneurship pockets—which enables them to create and explore new ideas in a more agile way.

As seen in the examples above, the use of SNA centrality metrics is quite popular in organizations and in project environments. In a social network, centrality refers to a network's structure, which results from how different entities are connected within that network's structure [6,10,45,46]. Research in SNA centrality metrics suggests that centrality metrics, such as degree (which can be an indicator of a network's activity potential), closeness (which can be an indicator of the independence potential of a network), or betweenness (which can be an indicator of control and communication between two different groups), can efficiently measure the importance, influence, prestige, prominence, and control of individual entities (people, groups, or organization) within a social network [10,45,46]. Furthermore, research argues that network centrality is correlated with informal power in project collaborative networks, which strongly influences coordination and decision making, especially in project environments [45,46].

Research shows also that dynamic interactive relationships (also called corporate behaviors) are complex by nature and cannot be completely explained by traditional social theory methods [47,48]. Such dynamic interactive relationships must rather be described and analyzed by the application of methods that are based in sociology, where the individual's social context in the process of making choices is taken into consideration [48]. In the fields of sociology and project management, several studies show that the most effective way of understanding the way dynamic interactions between entities across a period emerge, evolve, and eventually keep or disappear is through the application of SNA centrality metrics [10,14,20–22]. This is explained, due the ability of quantitatively measured behaviors (dynamic interactions) between members of a given social network, by transforming entities into nodes or points of a graph, and the relationships between them into preferential, measurable links.

In this line of thought, the proposed model in this work is aligned with the latest research conducted in the fields of sociology and project management in two dimensions. First, by applying SNA centrality metrics to quantitatively identify behavioral patterns in a project social network across a finite period of time, the proposed model in this work is in line with recent research that argues that the application of SNA centrality metrics is the only effective way to uncover hidden behavioral patterns in the mix of formal and informal networks of relationship [6,10,14,20–22]. Second, the proposed model in this work is fully aligned with recent sociology and project management research, as it analyzes some of the most important social networks in project management, such as communication, problem-solving, advice, and trust, as mentioned above.

3. Model Development and Implementation

3.1. Development to the Proposed Model

As already mentioned in the introduction, in this work is proposed a heuristic model to identify in a holistic way corporate behavioral risks in project environments. The proposed model was developed based on four fundamental fields, which are illustrated in Figure 1.

Figure 1. The four fundamental scientific fields that support the development of the proposed model in this work.

As illustrated in Figure 1, the first field that supports the development of the proposed model in this work is the project management scientific field. This field contributes to the proposed model in this work with the standard definitions and structure of a project, and the tools and techniques applied in project management.

The second field is the risk management scientific field. This field provides the proposed model with the standard definitions, approaches, and risk-management process frameworks that will be used across the development and implementation of the proposed model in this work. It provides the process of identifying, analyzing, measuring, treating, monitoring, and updating project cooperative behavioral risks (dynamic interactions) that emerge and evolve as the different stakeholders work together to deliver projects.

The third field is the corporate behavior scientific field. This field provides the proposed model with the definitions of the different corporate risk types and their characteristics in the project management environment.

The fourth and final field is the social network analysis scientific field. This field provides the proposed model with the tools and techniques to map, identify, and quantitatively measure different corporate behavioral patterns that emerge, evolve, and eventually continue or disappear as the different project stakeholders work together to deliver projects. More concretely, the SNA field (the SNA tools and techniques) will be used to identify and quantify the evolution of those different corporate behavioral patterns by analyzing four critical social project networks, through the application of social network analysis centrality metrics. The four critical social project networks are: (1) communication (which identifies, within the project stakeholders network, who communicates with who and how balanced

or unbalanced the project stakeholder's communication network is), (2) problem-solving (which identifies, within the project stakeholders network, who turns to who in search of expertise, know-how, or know-what regarding project-related matters), (3) advice (which identifies, within the project stakeholders network, who turns to whom in search of advice and support regarding project-related matters), and finally (4) trust (which identifies, within the project stakeholders network, who trusts whom regarding project-related matters). In Table 3 are described the four critical project social networks.

Table 3. Description of the four critical project social networks.

(1) Communication	The mapping of the communication network in a project social network enables one to analyze aspects related to how effective, efficient, and centralized (or de-centralized) the communication that occurs between the different project stakeholders that work together to deliver projects is. Aspects such as frequency, intensity, reach, and broadness are entitled to be analyzed. For this matter, data from project email exchange, surveys or questionnaires, or observations can be used to map the communication of a project social network.
(2) Problem-solving	The mapping of the problem-solving network in a project social network enables one to identify critical partners or sub-networks, whereby expertise flows regarding project-related matters. Aspects such as frequency, intensity, reach, and diversity are entitled to be analyzed in the problem-solving network. For this matter, data from project email exchange, surveys or questionnaires, or observations can be used to map the project problem-solving of a project social network.
(3) Advice	The mapping of the advice network in a project social network enables one to identify key project partners or subnetworks, whereby support and some project matter expertise flows. Aspects such as intensity (translated into dependency), broadness, and diversity are entitled to be analyzed in the advice network. For this matter, data from project surveys or questionnaires, or observations can be used to map the project advice network of a project social network.
(4) Trust	The mapping of the trust network in a project social network enables one to identify critical project partners or sub-networks, whereby trust and support (translated into professional and personal) is established. Aspects such as intensity, frequency, confidence, empowerment, and reliability are entitled to be analyzed in the trust network. For this matter, data from project surveys or questionnaires, or observations can be used to map the project trust of a project social network.

As illustrated in Table 3, each one of the four critical project networks have their own specificity regarding the identification of project behavioral patterns. However, even though each individual specificity is comprised in each of the four critical networks, they complement each other. This fact enables one to create a holistic approach regarding the identification and understanding of how collaboration emerges, evolves, and eventually disappears, as different project stakeholders work together across a project lifecycle.

In the proposed model in this work, for the communication network dimension, project email exchange data between project stakeholders will be used to map the communication network of the project social network. The problem-solving network will be mapped and analyzed with data collected in a project survey launched to all the project stakeholders. The advice network will be mapped and analyzed with data collected in on-site observations of all project stakeholders. The trust network will be mapped and analyzed with data collected in a project survey launched to all the project stakeholders. The construction of the assessment is to be agreed upon by the network analytics team or individual and the entity to be analyzed. This comprises, for example, the types of data collection methods (survey, observations, emails), as well as what and how many questions are to be launched in the survey. As previously mentioned, for each one of the four critical project networks, a respective network (also known as graph) will be created by applying SNA centrality metrics. An example of what each one of the four critical project networks look like is illustrated in Figure 2.

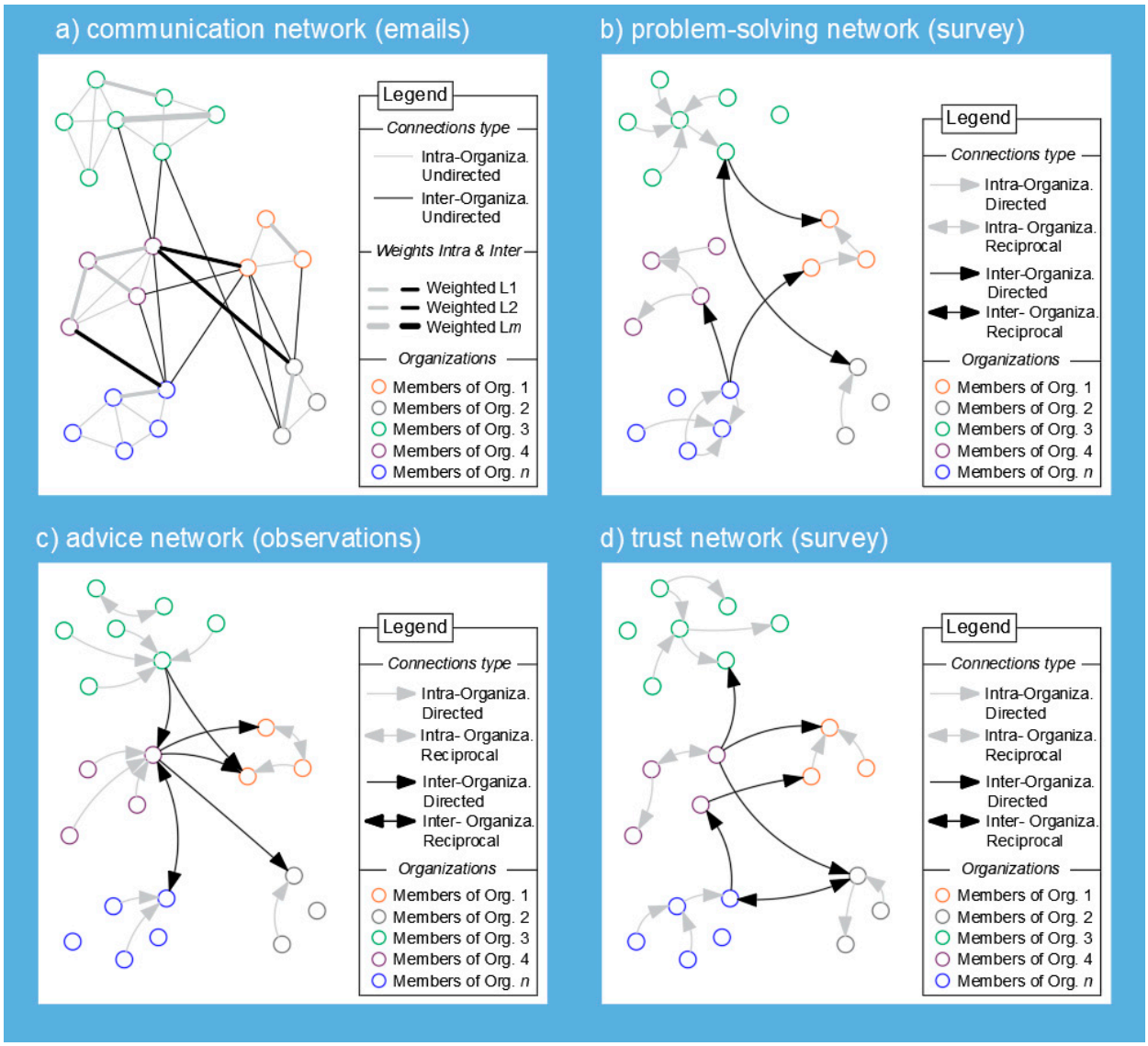

Figure 2. The four critical networks of the proposed model in this work: (**a**) communication, (**b**) problem-solving, (**c**) advice, and (**d**) trust.

In Figure 2 are illustrated the four different critical project networks that the proposed model in this work will analyze in detail. As previously mentioned, the project communication network will be mapped with data collected in project emails exchange. The resulting network is illustrated in Figure 2a (communication network). In Figure 2a are illustrated five different organizations that collaborate to deliver a given project. Each organization is represented by a different color. As the legend of Figure 2a illustrates, the employees of organizations 1, 2, 3, 4, and *n* are connected through lines between them. These represent the email communication network channels. In the communication network, the lines between the different organizations' employees may be weighted and classified into different customizable classes or levels, such as those indicated in the legend of Figure 2a (Weighted L1, L2, or L*m*). Such weighted linkages represent the number of emails that have been exchanged between any two given employees within a finite period. The communication network is characterized by a non-directional connection type. One link or line represents that there is a communication channel between two given entities wherein several emails have been exchanged across a bounded period of time. If no link exists between any two given entities, it means that no single email has been directly or indirectly exchanged between them. The links within the communication social network

are divided into interorganizational links (black lines) and intraorganizational links (grey lines). These represent the communication between different organizations and within an organization, respectively.

In Figure 2b is illustrated the problem-solving network. In this network are illustrated the same organizations as in the previous network (communication network), containing also their respective employees and a set of links between them. This network maps the connections (dynamic relationships) between the different employees of the different organizations with directed links. These type of links (directed) represent preferences, choices, or nominations, and can be classified into one-way-directed or reciprocal, as illustrated in the legend of Figure 2b. The problem-solving network is mapped with the answers collected by a survey addressed to all organization's employees that participated in project tasks or activities, where questions such as "who do you turn to in order to get help regarding a given project problem or challenge?" may be formulated.

The two networks of advice (Figure 2c) and trust (Figure 2d) follow the same principle as the problem-solving network regarding the mapping and analysis process. However, the data collection method may be different. To map the advice network, data collected in observations was used. This method implies an active monitoring process of organization's employees, regarding who they go to in order to get advice concerning project task or activities. However, the proposed model in this work is not by any means constrained to a given type of data collection method. This means that other data collecting methods may be applied if they collect valuable and reliable data to map the four different critical networks. The last network to be mapped is the trust network, as illustrated in Figure 2d. To map this network, data from surveys conducted of an organization's employees is collected, where questions such as "who do you trust to confide in about project-related problems or challenges without fearing retaliation?" may be formulated.

As can be seen in the problem-solving, advice, and trust networks, not all employees are connected either by a directed or reciprocal link. This means that those employees that were not nominated—for example, as being people whom others can trust—have no directed link attached to them. For example, in the problem-solving network illustrated in Figure 2c, there is one reciprocal connection between organizations *n* and 4 through one element of each organization. This means that one element of organization *n* trusts one element of organization 4, and vice-versa. In the same network, there are two non-reciprocal connections between organizations 4 and 1. In this case, and according to the network of Figure 2c, one element of organization 4 trusts two elements of organization 1. Another way to represent such relationships (when analyzing dynamic interactions between the different organizations) is by drawing one link from organization 4 to organization 1 with a numeric value of 2. This value represents the two nominations from the element of organization 4 to one element of organization 1. This representation is also known as the weight of a directional link.

3.2. Implementation of the Proposed Model

In Figure 3 is illustrated the implementation process of the proposed model in this work. The generic project lifecycle used by the proposed model in this work, which is illustrated in Figure 3, is adopted from the PMI (Project Management Institute) book of knowledge [4], and is constituted of four project phases.

Due to illustrative purposes, the detailed explanation regarding the implementation process of the proposed model in this work illustrated in Figure 3 only covers the first two project lifecycle phases (starting the project, and organizing and preparing). This does not mean that the implementation process of the proposed model in this work illustrated in Figure 3 is different in the remaining phases (carrying out the work and ending the project). In fact, the process is completely replicable across the other remaining project lifecycle phases. This also implies that the interpretation of results is done in a similar way across all the different phases of a project lifecycle. Moreover, regardless of the number of phases a project has, the implementation process of the proposed model always follows the same

principle that is explained in detail in Figure 3 in starting the project and the organizing and preparing phases, as we will see in the following.

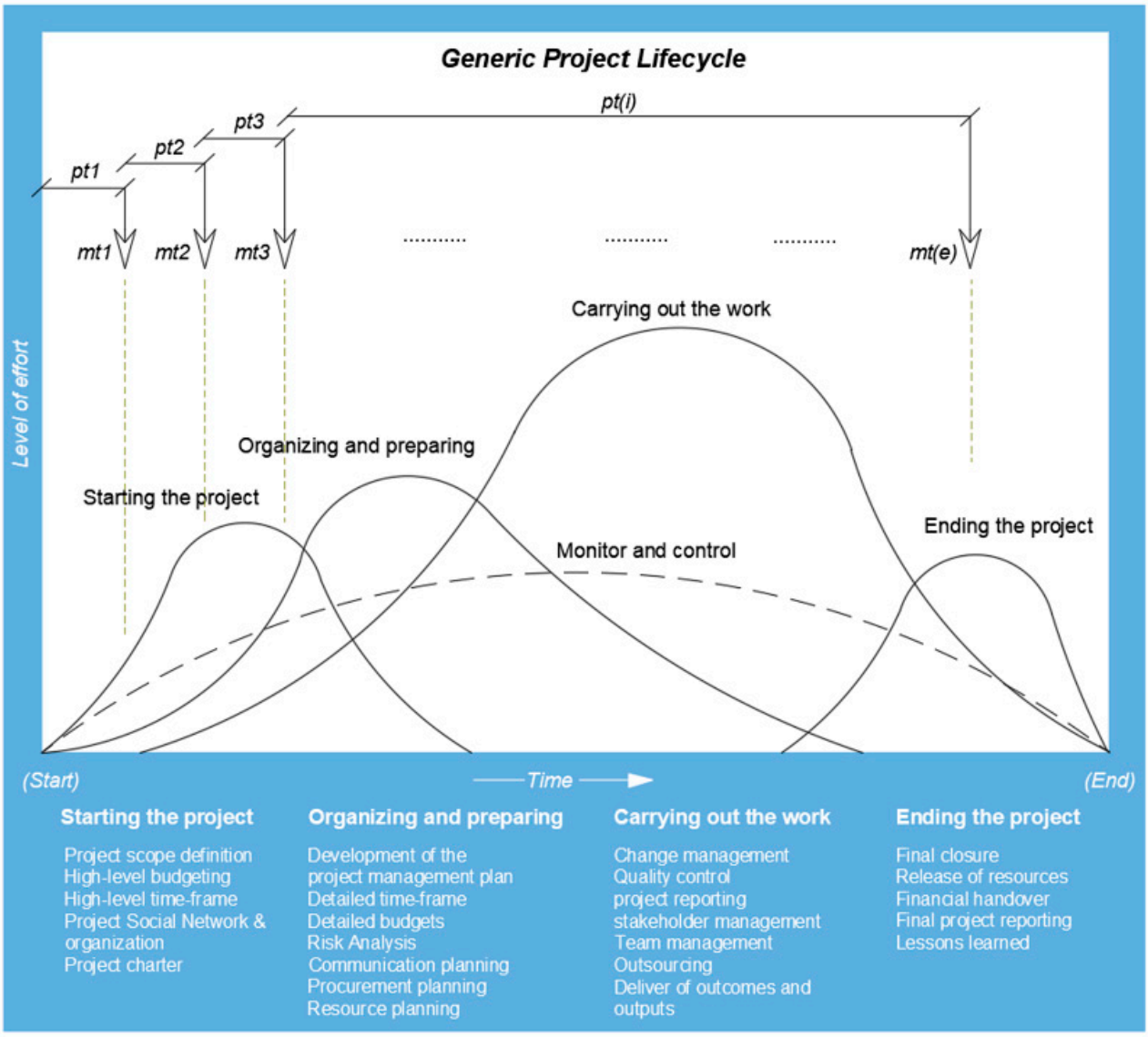

Figure 3. Implementation process of the proposed model in this work, adapted from [4].

In Figure 3 are illustrated the four typical different phases of a project lifecycle proposed by the PMI [4], and the respective expected level of effort for each one of the different project phases. The four project phases are: (1) starting the project (where the project scope, definition, and project charter are defined), (2) organizing and preparing (where the development of the project begins in all the its different dimensions, ranging from budgeting, to risk analysis, to resource planning, just to name a few), (3) carrying out the work (which is the execution of what has been planned, but also complementing support activities such as change management, quality control, and stakeholder management, just to name a few), and finally (4) ending the project (which comprises the final project activities, such as financial handover, release of resources, and collection of lessons learned, just to name a few).

In Figure 3 are illustrated the finite periods of time pt1, pt2, pt3, . . . , pt*i*. These represent the bounded period of time where the proposed model in this work will be applied. In Figure 3 are also illustrated the monitoring points (also called collecting points)

mt1, mt2, mt3, . . . , mt*e*. These represent simultaneously the length of a given pt*i* finite period of time, and when data will be collected and analyzed.

For a given period pt*i*—which comprises the time between any two given mt*e* (monitoring time) and mt*e* + 1—data regarding the interaction of the different stakeholders that work together to deliver a project is generated. This time-period is entirely customizable and can either be defined by the network analyst or the organization that conducts the assessment. For the purpose of analysis, the overlap between different project phases has no negative implication. This happens because the objective of the proposed model is not to clearly define the different phases of a project lifecycle, but rather to analyze how dynamic collaboration between different project stakeholders emerges and evolves within a finite or bounded period of time. In each monitoring time mt*e*, which includes the processes of collecting and analyzing data, the proposed model in this work will apply SNA centrality metrics to quantitatively measure the already mentioned four critical project social networks ((1) communication, (2) problem-solving, (3) advice, and (4) trust).

In Table 4 are illustrated the SNA centrality metrics that will be applied to quantitatively measure the four critical project social networks, as well as the respective data collection method, and the objective of each centrality metric.

Table 4. Proposed model SNA centrality metrics.

Critical Project Social Networks	Data Collecting Method	Project Social Network Analysis Metrics and Objectives
(1) Communication	Emails: All exchanged email data (sent and received) between all participating project stakeholders related to project information regarding a given project phase. To be collected at the end of each project time mt*n*.	Objective: Identify who is central and who is peripherical within the project email exchange network. SNA Metric: Weighted in-degree $C_{WID}(n_i) = \sum_j x_{ji}$ (a), Where: C_{WID} = total weighted degree of an entity within a graph n = total number of entities within a graph for $i = 1 \ldots, n$ x_{ji} = number of links and their weight from entity j to entity i, where $i \neq j$, and vice versa, function of directed or undirected graph
(2) Problem-Solving	Survey: Addressed to all project stakeholders' members that have participated in a given project phase. Data is collected at the end of each project time mt*n*.	Objective: Identify how the problem-solving network is established across the project social network. SNA Metric: In-degree $C_{ID}(n_i) = \sum_j x_{ji}$ (b), Where: C_{ID} = total degree of an entity within a graph n = total number of entities within a graph for $i = 1 \ldots, n$ x_{ji} = number of links from entity j to entity i, where $i \neq j$, and vice-versa, function of directed or undirected graph
(3) Advice	Observation: All project stakeholders' dynamic interactions regarding the search for advice concerning project related matters observed on-site. Data is collected across a period of time pt*n*.	Objective: Identify how the advice network is established across the project social network. SNA Metric: In-degree (see Equation (b))
(4) Trust	Survey: Addressed to all of an organization's members that have participated in a given project phase. Data is collected at the end of each project time mt*n*.	Objective: Identify who trusts who, regarding project related information. SNA Metric: In-degree (see Equation (b))

As illustrated in Table 4, to analyze the communication network, the weighted in-degree SNA centrality metric will be applied to identify who is central and who is peripherical within the project email exchange network. To analyze the problem-solving network, the in-degree centrality metric will be applied to identify how the problem-solving network is structured across the project social network. To analyze the advice network, the in-degree centrality metric will be applied to identify how the advice network is structured across the project social network. Finally, to analyze the trust network, the in-degree centrality metric will be applied to identify how the trust network is structured across the project social network.

4. Case Study

4.1. Introduction to the Case Study

The case study introduced in this section was conducted by an international market leader food and beverage organization at the end of 2018 in Europe. The case study was aimed at the analysis and continuous monitoring of project stakeholders' behaviors' importance in project evolution, and how changes in behavioral patterns could impact project deliverables and ultimately project outcomes. For this matter, the proposed model in this work was applied. The organization that conducted the following case study—named in this work, due to privacy reasons, organization A—won a contract to develop and implement a food-related project—named project 1 in this work—in mid-Europe. The project, which consisted in the implementation of a new production line of an end-user good for one of its customers in Europe, was budgeted at about 5 million euros and meant to be completed within a 3-year period of time. Organization A sub-contracted another organization—named organization 1 in this work—to accomplish project 1. Organization 1 was also responsible for the outsourcing of some project-1-related tasks and activities to other specialized organizations in four different areas: (1) mechanical installations, (2) automation engineering, (3) electrical engineering, and (4) processing engineering. Organization 1 was responsible for the mechanical installation works in project 1 and contracted the following organizations: organization 2, which was responsible for the automation engineering works in project 1; organization 3, which was responsible for the electrical engineering works in project 1; and organization 4, which was responsible for the processing engineering works in project 1. All organizations agreed to participation in the case study conducted by organization A. The number of employees in each of the selected organizations involved in accomplishing project 1 varies as follows: organization 1, 23 employees; organization 2, 5 employees; organization 3, 9 employees; and organization 4, 6 employees. The case study conducted by organization A involves the application of the proposed model in this work to identify, quantitatively measure, and monitor the impact of the different stakeholders' (organizations 1, 2, 3, and 4) dynamic behaviors across the different phases of project 1 on project 1 outcomes, by analyzing the already mentioned four critical project social networks ((1) communication, (2) problem-solving, (3) advice, and (4) trust).

Organization A believes that understanding how collaboration is occurring between the different project's stakeholders—which is mirrored across the different dynamic behaviors between project 1's stakeholders—could enable organization A to, in a timely manner, take corrective measures to minimize the potential negative impacts and optimize the potential positive impacts on project 1's deliverables. The assessment was conducted by a dedicated team belonging to Organization A (which is referred to in the present case study as an external team regarding project implementation) that received training in network analysis, namely in the development and implementation of the proposed model in this work.

Finally, Organization A believes that by applying the proposed model in this work, organization A did not only proactively act to increase the chances of project success, but also promoted the sustainable long-term cooperative partnership between the project's participating stakeholders in further project partnerships.

4.2. Application of the Proposed Model and Interpretation of Results

In this section will be presented an extract of the complete application of the proposed model, focused on the organizing and preparing phase according to the steps defined in Table 2. It includes the implementation of the proposed model according to Figure 3 and the application of SNA centrality metrics according to Table 3.

The results of the assessment conducted across organizations 1, 2, 3, and 4 illustrated in Figure 4 took place around the first quarter of the project, in the phase of organizing and preparing. It comprises the analysis of four project social networks decided by Organization A (communication, problem-solving, advice, and trust network), as is also suggested by the proposed model in this work.

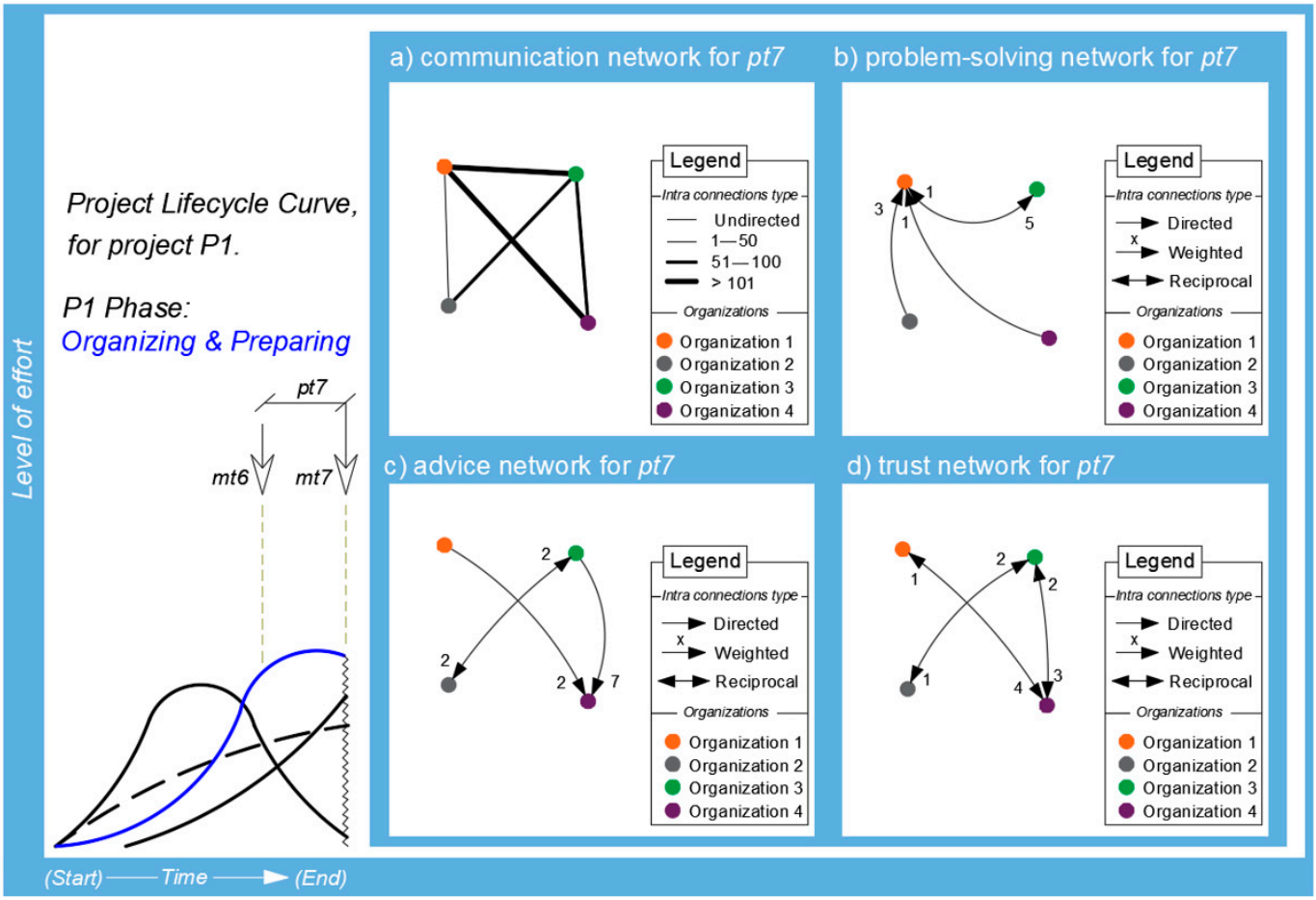

Figure 4. Results of the application of SNA centrality metrics to the four critical project social networks of project 1, where sub-figures (**a**–**d**) are the communication network for pt7, the problem-solving network for pt7, the advice network for pt7, and the trust network for pt7 respectively.

In Figure 4 are illustrated the results the assessment conducted across organizations 1, 2, 3, and 4 regarding the four already mentioned critical project social networks.

In the left side of Figure 4 is illustrated project 1's first lifecycle phase of organizing and preparing (represented with the blue line), which is the phase that corresponds to the case study illustrated in this work regarding the application of the proposed model. Within the four boxes (a–d) in Figure 4 are illustrated the results of the application of SNA centrality metrics for this time period of project 1, according to Table 3, regarding the four critical project social networks of (a) communication, (b) problem solving, (c) advice, and (d) trust, respectively.

Although all phases of project 1 have been analyzed by the proposed model in this work to identify corporate behavioral risks, in the present work (and in this section, namely the case study), only the application of the proposed model within the project's pt7 period will be illustrated and described, which corresponds to the period between mt6 and mt7, as illustrated in the left side of Figure 4. This is so due to paper length constraints and redundancy analysis.

Email-communication-related data was collected in the mt7 monitoring time, and contained all the project email communication between project 1's stakeholders (organizations 1, 2, 3, and 4) within the pt7 time period. The respective network is illustrated in Figure 4a. Project-related email data was collected and filtered by the external network analyst team, according to Table 4.

Problem-solving-related data was collected through a survey conducted on all of project 1's stakeholders in the mt7 monitoring time. The respective network is illustrated in Figure 4b. The question used to create and later map this network was the following: to whom do you usually turn to get an effective solution for a problem or a project challenge? The question used to create and later map this network was designed by the external analyst team and agreed upon by Organization A's top managers. The chosen question, although not being very specific, aims to capture and map a project social network that explicitly shows the dependencies among project stakeholders related to project technical solutions.

Advice-related data was collected through a set of daily observations, conducted by elements of the network analytic team of Organization A, of all of project 1's stakeholders across pt7. The respective network is illustrated in Figure 4c. To create and later map this network, on-site observations targeting personal communication (face-to-face (F2F) small talk and project-related meetings) were recorded, aiming to capture interactions regarding the search for advice and guidance related to project tasks and activities. For example, these observations comprise the search for help from a project stakeholder regarding a project activity or task within the period pt7.

Trust-related data was collected through a survey conducted on all of project 1's stakeholders in the mt7 monitoring time. The respective network is illustrated in Figure 4d. The question used to create and later map this network was the following: to whom do you usually turn or who do you trust to discuss or present new ideas regarding the project evolution without fearing retaliation?

This question was proposed by the analytics team and agreed to by Organization A's top management. It aims to uncover the collective innovative capacity of the project social network while simultaneously reflecting the social behavioral safety level.

In the right side of Figure 4, the organizations are represented by the different bold colored circles, which represent all the employees from each organization, as previously illustrated in Figure 2.

Turning back to Figure 4a, it illustrates the communication network for the pt7 time period of project 1's organizing and preparing phase. This network is characterized by an indirect connection type between all of project 1's stakeholders, as illustrated in the legend of Figure 4a. In this network, the lines between any two given two organizations represent project 1's exchanged email network for the pt7 period. For example, between organizations 1 and 3, according to the line thickness illustrated in the legend of Figure 4, more than 101 emails have been exchanged within the pt7 period of project 1's organizing and preparing phase. On the other hand, within the same pt7 period, very few project-related emails have been exchanged between organizations 1 and 2 (less than 51 emails). Still, between organizations 2 (automation engineering, 5 workers) and 4 (process engineering, 6 workers) within the pt7 period of project 1's organizing and preparing phase, zero emails have been exchanged. Such an event (behavior) should represent an alert for organization A. Although there may have been many different reasons for this behavior between organizations 2 and 4, it means that some of the email-information that flew between the other organizations did not flow through organization 4. Such behavior may say a lot regarding the communication degree between organizations 2 and 4. In such

cases, a further investigation is recommendable (also known as a follow-up assessment), either by analyzing other networks, or by conducting follow-up interviews with involved project stakeholders (which in this case are organizations 2 and 4) in order to uncover the real reasons behind such behavior.

Another interesting conclusion that arises from observing the communication network is that for the pt7 period, not all project-related information that was exchanged within the email network reached all of project 1's stakeholders in a balanced way. This can be seen by the different number of exchanged emails between project 1's stakeholders. Moreover, in this case, organization A should undertake further research (and take actions as needed) to assure that all necessary information reaches the respective receptor, and that in the next phases, that it not only reaches the respective receptor, but that it also does so in a timely manner. Finally, we can conclude that organizations 1 and 3 have a central position within the communication network of project 1. On the other hand, we can also conclude that organizations 2 and 4 are to a certain extent peripherical organizations (or less central than the previous mentioned organizations) within project 1's email communication network.

In Figure 4b is illustrated the problem-solving network for the pt7 period of project 1's organizing and preparing phase. This network is characterized by a directed network type where the links or connections between project 1's participating organizations (stakeholders) indicate a preference or a choice, which may still be reciprocal or not. For example, it can be clearly seen that most organizations heavily rely on organization 1 when it comes to solving project-related issues or problems. Organization 1 has a total of 5 nominations (3 nominations from organization 2, 1 nomination from organization 4, and 1 nomination from organization 5). At this stage, it can be concluded that there is a high dependency from organizations 2, 3, and 4 on organization 1, regarding who to turn to get project 1's problems and challenges solved. This behavior may represent a risk (threat) to the accomplishment of project 1's deliverables. Such a risk may be explained as follows: by overloading organization 1 members with constant problem-solving requests, it may lead to answering delays within organization 1 members, which in turn may result in information exchange bottlenecks. This, in turn, may originate critical project delays in project activities or tasks. Furthermore, it seems that are no valuable competencies in organizations 2 and 4 that organizations 1 and 3 can rely on (need) to get project 1's problems or challenges solved.

Still, in this network some reciprocity level can be observed between organizations 1 and 3. However, while organization 1 has 1 problem-solving request from organization 3, organization 3 has 5 nominations from organization 1. This behavior clearly represents a non-balanced reciprocity status within project 1's social network regarding problem-solving initiatives.

Finally, the network results illustrated in Figure 4b clearly provide organization A with a unique picture of how collaboration regarding problem-solving is evolving within the pt7 period of project 1. This way, organization A should be aware of the negative or positive consequences (behavioral risks) that may arise from such observed dynamic behaviors, and conduct follow-up interviews in order to uncover the underlying reasons that led to such dynamic interactions.

In Figure 4c is illustrated the advice network for pt7 of project 1's organizing and preparing phase. This network is also characterized by a directed network, where the links from one organization directed to another organization represent a choice or preference. As can be seen in the advice network, for pt7, organization 4 has more advice requests than all the remaining organizations. Organization 4 received a total of 9 nominations (2 nominations from organization 1, and 7 nominations from organization 3). Organization 4 has by far the highest number of nominations (more than double the other nominated organizations) in the advice network for pt7 illustrated in Figure 4c. In the advice network, organizations 3 and 2 each have 2 nominations. These nominations are totally reciprocal. This means that there is a full balanced relationship between organizations 2 and 3 regarding the search for advice on project-related matters. Interesting to compare

is the behavior of organization 1 in the advice network and in the problem-solving network. Although organization 1 had the highest number of nominations in the previous network (the problem-solving network), when it comes to the advice network, organization 1 abruptly drops to zero nominations. This extreme behavior change may represent a corporate behavioral risk. This could mean that organization 1 is heavily requested to solve project-related problems; however, it seems that organization 1 has no meaningful advice regarding project-1-related activities for the other organizations. At first sight, such dynamic behaviors seem to be contradictory. However, when deeply analyzed, it is not so unusual to find people in an organization that are known as the top problem-solvers (also called subject matter experts); however, they do not really fit within the social network they are embedded in. Such people were characterized by Cross and Parker as peripheral people [42]. According to [42], peripheral people can be divided into peripheral experts and peripheral intentionally. In this case, regarding the extreme behavior change of organization 1 in reference to the problem-solving and advice networks, organization A should conduct follow-up interviews to uncover which peripheral type is emerging within project 1's social network regarding organization 1. Still, such an abrupt shift regarding the influence of certain organizations in a given social network—as is observed in organizations 1 and 4 when analyzing the problem-solving and advice networks—may represent that collaboration is occurring in two different extremes, as mentioned in the literature review section. The first extreme is characterized by a lack of collaboration regarding the contributions of other organizations—organizations 2 and 4—to the problem-solving network, and the advice network—organization 1—as can be observed in Figure 4b,c. The second extreme may be characterized as a collaborative overload status (as can be observed in Figure 4b,c, where organization 1 plays by far an extremely central role regarding the contributions to the problem-solving network, and organization 4 plays by far an extremely central role regarding the contributions to the advice network, respectively). Both lack of collaboration and collaborative overload status are, according to research [13,18], highly prejudicial to the organizational collaborative performance, threatening project 1's deliverables.

Finally, the last network to be analyzed in this work is the trust network for p7, as illustrated in Figure 4d. This network is particularly interesting and important because it may shed light on the observed behaviors in the two already-analyzed networks (problem-solving and advice networks). Trust, according to several studies [6,10,14,22], is a fundamental pillar of efficient collaboration between organizations that work together to achieve a common goal. Trust is, in fact, fundamental to diversity and inclusion, because it opens the communication paths between and within an organizations member's and fuels them with energy and psychological safety [13–15]. This, in turn, boosts collaboration performance and innovation [13,15]. In Figure 4c is illustrated the trust network for the pt7 period of project 1's organizing and preparing phase. In this network, organizations 3 and 4 play a central role in project 1's organizing and preparing phase regarding the trust dimension. Organizations 1 and 2 are, to a certain extent, isolated within the trust network when compared with the other organizations. This can be seen in the number of nominations they have. Once again, organization 4 plays a central role, now in project 1's trust network, with a total of 7 nominations, immediately followed by organization 3, with a total of 4 nominations. The behaviors observed in organizations 4 and 3 regarding the trust network are to a certain extent in line with the behaviors observed in the previous network (the advice network). This happens because both networks (trust and advice) are related regarding their intrinsic meaning. In other words, the likelihood of getting advice from someone who one trusts is higher than from someone who one does not trust. The same may not be observed when analyzing trust and problem-solving networks because both networks are not so closely related regarding their intrinsic meaning. This fact may explain why there is a shift in the choice of the most influential organization in the project's social network as it moves forward. For example, between organizations 1 and 4, there has been a relatively good collaboration level, which can be observed in the communication, problem-solving, advice, and trust networks. In fact, both organizations have always been

connected across the four networks—a fact that is not observed between any other two given organizations in project 1's pt7 time period. On the other side, the collaboration level in all four networks between organizations 2 and 4 seems to be poor or very poor, because there is no single connection between them in all four analyzed critical social project networks. A particular finding in the trust network has to do with the reciprocity aspect. In all existing connections in the trust network, there is reciprocity to be observed, but not always with the same intensity. For example, between organizations 2 and 3, there is a line between them with a value of 2 from organization 2 to 3, and a value of 1 in the inverse direction. This means that the trust network is unbalanced. This may represent a trust issue (or risk) within the project 1 social network. Ultimately, this issue may lead to project behavioral risks which can be translated into mistrust among project 1's stakeholders, which in turn may lead to a poor accomplishment of project tasks and activities, and to the emergence of organizational silos. Still, in the trust network, organization A should conduct further investigations to understand the underlying reasons that lead to the observed behaviors illustrated in Figure 4d.

Until now, the analysis process conducted on the four critical networks were done in a unique timeslot comprised of the time between mt6 and mt7. To better understand how the four critical project social networks evolved across a longer period (within a particular phase or across multiple phases of a given project's lifecycle), one needs to plot the results from the previous analysis (if they have been previously done) regarding the following time periods: from mt1 to mt2, from mt2 to mt3, from mt3 to mt4, from mt4 to mt5, and from mt5 to mt6. Doing this results in a longitudinal evolution analysis, which would stretch across a larger period regarding the four critical project social networks. The benefits of such longitudinal analysis are that it enables one to better understand the variations that did occur (if they did occur) across a given bounded time period, allowing the identification of key events that were responsible for smooth or abrupt shifts regarding the different corporate behaviors that emerge and evolve as the project's different stakeholders deliver projects. Performing such longitudinal analysis is like taking a set of real time pictures of how the different project stakeholders have been working together (dynamically interacting) to achieve a common goal across a finite period. For this matter, the data analysis process of two of the four networks (advice and trust) between mt1 and mt7–which represents the period between the beginning of the phase of organizing and preparing (mt1), until the actual point (mt7) of the phase of organizing and preparing—will be presented in this section. In Figure 5 is illustrated the evolution degree of the advice network between project 1 over the mt1-to-mt7 period.

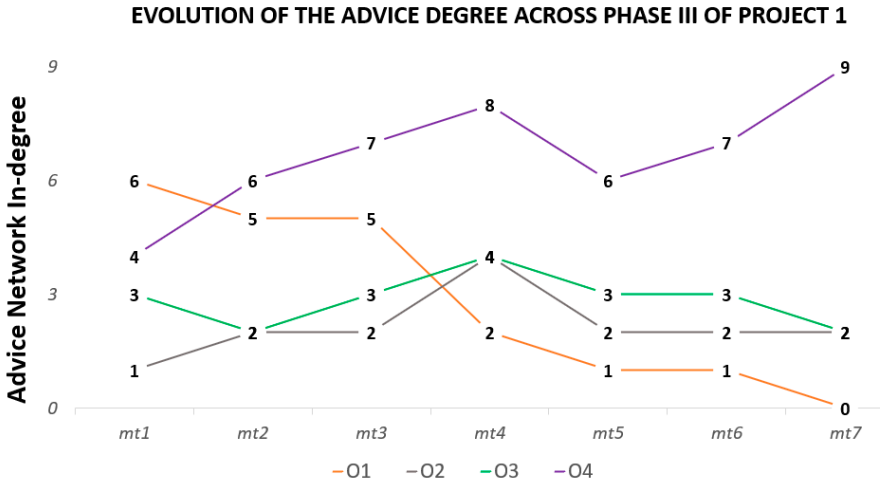

Figure 5. Advice degree evolution throughout the organization and preparation phase of project 1.

In Figure 5 are illustrated the four organizations (O1, O2, O3, and O4) that participated in the organizing and planning phase of project 1 from mt1 until mt7. Each organization evolution illustrated in Figure 5 is characterized by a respective color, as illustrated in Figure 4. As can be seen in Figure 5, organization 4 seems to have continuous growth between mt1 and mt7 regarding the advice network within project 1's social network. On the other side, it seems that all the remaining organizations (O1, O2, and O3) have been considerably decreasing their contribution to the advice network in the same period. The dynamic behavior identified in pt7—which corresponds to the period between mt6 and mt7—seems to be the result of an "older identical evolution" that can now be seen in the previous periods of time (from pt1-mt1 up until pt7-mt7), as illustrated in Figure 5. This means that from mt3 onwards, there has been a certain acceptance within the project 1 social network that only organization 4 is able provide valuable advice regarding project-1-related matters. It is now quite clear to see (observing the evolution in Figure 5), from when it began, the shift regarding the advice network of the project 1's social network. Moreover, in the beginning of the project 1 organizing and preparing phase, organization 1 was the organization with the highest nomination number regarding the advice network. However, as project 1 moves along the time axis, organization 1 has abruptly dropped its leading position in the advice network, namely from mt3 onwards until mt7. On the other side, the evolution of the advice network regarding organizations 2 and 3 seems to be quite parallel across time. This quite balanced advice network level observed in organizations 2 and 3 seems like it could be translated into a reciprocal dynamic interaction type, as is observed in Figure 4 in the advice network for pt7.

In Figure 6 is illustrated the evolution degree of the trust network, in the period between mt1 and mt7, within the project 1 social network.

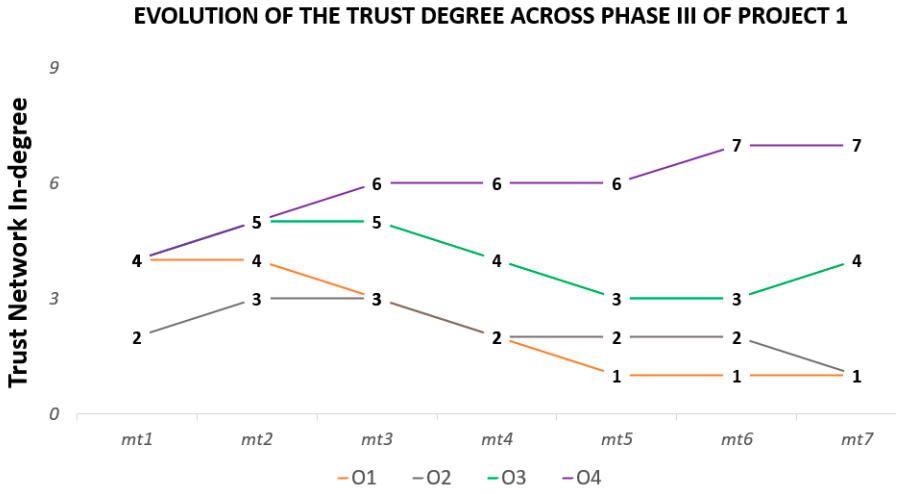

Figure 6. Trust degree evolution throughout the organization and preparation phase of project 1.

As can be seen in Figure 6, the trust network has a lower variability across time when compared with the previous longitudinal analysis on the advice network. This only reflects the reality regarding trust: it takes time to gain, but it can be lost very fast. As we move along project 1's preparing and organizing phase towards its end, it can be observed that organization 4 has increased its trust level in a very sustainable way. Once again, organization 4 has been gaining a very central position within the project social network regarding trust, namely from mt2 onwards. Simultaneously, but in the inverse direction, organizations 1 and 3 have become more peripheral within the project 1 trust network. As previously said, trust is a fundamental pillar to effective collaboration, and as can be observed in Figure 6, it seems that there is a low level of trust between all the organizations that participated in the accomplishment of project 1 in the organizing and preparing phase. Such a behavioral shift regarding the trust network may represent a threat to the stability of

the project's social network, as mentioned before. In this case, organization A should take into consideration a further analysis (follow-up assessment) to uncover the real reason(s) that led to the observed dynamic behaviors illustrated in Figure 6, and if necessary, consider the implementation of corrective or supportive measures aimed at the creation of trust among project 1's different stakeholders, to increase the chances of project success.

5. Conclusions, Implications, and Further Developments

The research conducted in this work, which led to the development of the proposed model, addresses different dimensions of different areas beyond the already mentioned fundamental four fields (1) project management, (2) risk management, (3) corporate behavior, and (4) social network analysis) that were used to develop the proposed model in this work. This provides the research conducted in this work with an innovative and expansionist character, laying the foundations for further research in this intriguing, interesting, and underexplored scientific field, which is essentially characterized by the quantitative identification of the impact that human dynamic relationships (dynamic behaviors) have on outputs and outcomes.

The main objective of this work is to present a heuristic model that, in a holistic and effective way, identifies, quantitatively measures, and analyzes how the different corporate behavioral patterns may turn into project behavioral risks, and thus influence project's outcomes across the different phases of a given project lifecycle. This is done by analyzing four critical project social networks ((1) communication, (2) problem-solving, (3) advice, and (4) trust) that usually emerge and evolve as a cooperative project is being delivered, and are the result of the mix of formal and informal networks of collaboration.

The research conducted in this work contributes to answer one of the fundamental research questions in project management, which can be stated as follows: to what extent do the different dynamic behavioral interactions between the different project stakeholders across all the different phases of a given project lifecycle positively or negatively impact a project's outcome?

As seen in the case study section, the application of the proposed model in this work benefits organizations with unique and actionable insights by answering the mentioned research question, which, in turn, enables organizations to better support (plan, guide, and monitor) cooperative projects' tasks and activities. This, in turn, is a critical asset to drive long-term sustainable cooperative partnerships. Furthermore, this fact is supported by several studies in the project management field, which argue that organizations that exert more control over inter- and intraorganizational project environments clearly increase the chances of project outcome, compared to those that leave inter- and intraorganizational collaboration to chance [13,15,49].

The model proposed in this work also enables organizations to accurately quantify the extent to which informal and formal project organizational networks of relationships may be correlated to project outcome. This particular aspect can be considered as a unique and effective approach to, in a quantitatively way, support or contest research that argues for the importance of informal organizational networks (sometimes more than formal organizational networks) in successful project outcomes [6,10,13,15,19], and research that argues that other factors, such as education, business referral, and expertise, are of much greater importance than informal organizational networks in successful project outcomes [50].

Still, the proposed model in this work is aligned with the latest organizational trends regarding the improvement of organizational performance and innovation, simultaneously being sustainability-oriented and customer-centric, through the application of digital transformation and industry 4.0 strategies. It is common to hear and read that data is the new oil [51–53]. This quote—coined by British mathematician Clive Humby in 2006 [51]—seems to be alive and kicking. In fact, as organizations generate countless gigabytes of data on a daily basis, they also increase their data analysis activities in order to extract unique and meaningful insights that may help them do more accurate (also known as

data-informed) decisions. This, in turn, enables organizations to craft more data-driven strategies, increasing their performance and innovation levels, as well as their chances of success. Furthermore, the incorporation of the proposed model into an organizational business intelligent architecture is able to transform the proposed model in this work into a potential supervised machine learning model, which organizations can use for the development of integrated intelligent strategic risk management solutions. This, in turn, will enable a faster and more accurate descriptive, predictive, and prescriptive analysis, and still enable a correlational analysis by adding other organizational departments, such as HR, sales, marketing, and so on.

Finally, the implementation and application of the proposed model in organizations positively contributes to actual social, economic, and environmental sustainability challenges. In organizations, sustainability can be interpreted as a holistic, consistent, and incremental growth process that concentrates on the long term, instead of on short-term approaches only [10,14]. The ability provided by the proposed model of accurately knowing where, when, and what must be done to improve collaboration between the different project stakeholders to deliver projects with higher success chances is a key pillar that goes across the three major pillars of sustainability (social, economic, and environmental). The sequence goes as follows: identifying, quantifying, and predicting corporate project behavioral risks enables organizations to, in a timely manner, develop more data-informed decisions for the optimal management of necessary resources (people, time, money, just to name a few) for the successful accomplishment of projects. This, in turn, enables organizations to become leaner, and thus, increases the chances of achieving sustainable competitive advantages.

5.1. Proposed Model in This Work and Literature Research Implications

The proposed model in this work addresses two major organizational cooperative risks. These are (1) ambiguity risks and (2) behavioral risks, as proposed by [12,27], respectively. The proposed model provides a valuable and unique contribution to the corporate behavioral risk scientific field, which, according to several studies [6,10,12,13,27], is still underdeveloped.

The application of SNA centrality metrics enables one to quantify how much the mix of formal and informal networks of relationships impacts project outcomes.

The proposed model in this work offers an effective approach to obtain quantitative results that can support or contest—in a more data-informed way—research that argues over the fundamental role of the mix of formal and informal organizational networks in innovation and performance [13,18,40,54], and research that argues that other factors, such as education, business referral, and expertise, are of greater importance than the mix of formal and informal networks of relationships [50].

The proposed model also contributes to the organizational transformation trend, in the sense that it provides organizations with a new approach for managing corporate behavioral risks across the different phases of a project lifecycle by the application of quantitative information, technology, tools, and approaches, as is achieved with the incorporation of the proposed model into a typical business intelligence architecture. Such a transformation involves not only the implementation of a new technologies across an organization's structure, but also the adoption of a new way of working, as suggested by several studies in the field of organizational management and sociology [10,12,13,15]. This, ultimately, could lead to the development of new organizational theories and approaches.

5.2. Proposed Model in This Work and Managerial Implications

From a managerial perspective, the proposed model in this work addresses several different critical organizational dimensions. The main objective of the proposed model is to provide organizations a practical heuristic risk model to holistically and efficiently manage corporate behavioral risks, which, according to research [55], is still a major obstacle to organizations more often engaging in collaborative projects.

Because the proposed model quantitatively uncovers corporate behavioral patterns across a bounded period of time, organizations can better understand and better correlate different behaviors with different project outcomes, and thus make the decision-making process more data-informed, rather than uniquely relying on gut feelings and organizational key influencers' opinions.

The proposed model in this work provides organizations with a unique and valuable tool to, in a quantitative way, identify hidden corporate dynamic behaviors, which, according to latest research [6,10,12,48], cannot be understood and managed by the application of traditional project management tools and techniques.

Furthermore, the proposed model maps (uncovers) and analyzes four critical project social networks ((1) communication, (2) problem-solving, (3) advice, and (4) trust), which, according to several studies [6,12,13,15,29,45,46,56]—as they center the analysis in the centrality of a social network—, are the networks that are most unique and valuable in providing insight regarding the understanding of how corporate behavioral patterns may evolve to behavioral risks and thus impact project's outputs and outcomes.

The application of the proposed model in organizations provides a valuable and measurable historic evolution regarding collaboration between the different project stakeholders that participate in collaborative projects across the different phases of a project lifecycle. In other words, the proposed model enables one to generate lessons learned in a quantitative way that can be better understood and can be correlated to project outputs and outcomes. This aspect strongly contributes to the achievement of sustainable competitive advantages in the short-, medium-, and long-term, regarding cooperative partnerships. Still, the proposed model provides organizations a unique push towards the adoption of a new way of thinking about organizational work, and the implementation of new technologies that ultimately contribute to a more effective and efficient working culture.

The model presented in this work can be fully automated once efficiently integrated into an organizational business intelligence architecture. By doing so, the proposed model in this work can access data and perform analysis in a more bias-free way, while simultaneously eliminating or minimizing data collection down-time, contrary to the traditional process of, for example, answering surveys in an online project-dedicated platform (also called pulse surveys).

Still, the proposed model in this work contributes to the transformation process from a reactive reporting organization (recording past business events) towards a more responsive and intelligent organization, which is characterized by the transformation of data into valuable and unique business insights that improve performance and innovation by helping take the right decisions at the right time in a more data-informed way. This represents a whole new paradigm in organizations across their traditional organizational value-chains.

Finally, it can be concluded that the proposed model in this work provides organizations with a heuristic model to better plan and manage their corporate partnerships, which in turn will help them to optimize resource usage, while simultaneously leading them to a leaner organization, positively contributing to the three fundamental pillars of sustainability ((1) economic, (2) social, and (3) environmental) in a more effective way.

5.3. Proposed Model in This Work and Ethical and Legal Considerations

The proposed model in this work accesses and analyzes data that can be classified as sensitive and confidential by many organizations that deliver projects. Many organizations may not want such project-related information that flows across the different project stakeholders across a project lifecycle to be accessed and/or exposed. Therefore, the implementation and application of the proposed model in this work is totally dependent on the acceptance of the competent authorities, at both the organizational and national levels, that administer the respective legal and ethical issues, as is the case of the GDPR (General Data Protection Regulation) regulations applied in European countries. Furthermore, for a healthy application of the proposed model in this work, all the project stakeholders

that participate in the delivery of a project should be informed in advance that project behavioral information will be accessed and analyzed for the purpose of controlling and monitoring project evolution, thus minimizing the chances of project failure.

5.4. Suggestions for Future Research

The implementation and application of the model proposed in this work may represent a certain challenge for organizations. This may happen as organizations do not yet have the necessary technologies and/or working culture that enables the proposed model in this work to efficiently identify corporate behavioral risks. To efficiently implement and apply the proposed model in this work, it is recommended that organizations first create an organizational architecture (for example, the integration of the model proposed in this work into an organizational business intelligence architecture), where data can be collected, stored, and available to be analyzed. Unfortunately, such a step may not be possible for many organizations. Becoming a data-literate organization—which is characterized by the ability to understand, engage, analyze, and reason with data—is still a challenge for many organizations. Therefore, further research should be also conducted into finding alternative ways (more accessible to the majority of organizations) that enable organizations to acquire technology that enables them to democratize (make accessible to everyone, bottleneck-free, except if it is considered confidential or highly sensitive), normalize (standardized—the same values, expressions, language, and so on), and create or acquire relational data across different applications and geographies.

The model proposed in this work collects data from project emails, project surveys, and project observations. However, as there are several project-information-related flows across other communication channels, such as phone calls, corridor meetings, and virtual communication platforms, research in the data collection methods field should be conducted in order to create mechanisms to access data in a way that would not go against GDPR regulations, namely regarding the access to private data.

Still, in order to support the applicability of the proposed model in the identification of project cooperative behavioral risks, the implementation and application of the model proposed in this work in a broader group of organizations that deliver projects is suggested. By doing so, it would be possible not only to improve the application process of SNA centrality metrics that are part of the actual version of the proposed model, but also to gain more insight regarding the impacts of dynamic corporative behaviors in project outcomes, and thus generalize (correlate) cooperative dynamic behaviors with project outcomes with a higher degree of likelihood.

Finally, further research should be conducted to explore the capabilities of other existing SNA centrality—but not only centrality—metrics regarding the quantification of cooperative behavioral patterns.

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Factors Influencing Collaborative Innovation Project Performance: The Case of China

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Abstract: This study conducted a comprehensive and systematic investigation of the influencing factors for collaborative innovation project (CIP) performance. First, a theoretical framework model was constructed, and then a structural equation model (SEM) was used for an empirical analysis of 199 CIPs. Furthermore, we divided the factors into tangible and intangible categories and considered the impact mechanism of nine typical factors on project performance. The results are as follows: (1) All nine factors had a significant positive impact on the performance of collaborative innovation projects, among which benefit distribution and collaborative innovation capability were the most important. (2) Benefit distribution, resource dependence, organizational climate, and collaborative innovation affected project performance, both directly and indirectly. (3) Effective communication, leadership support, knowledge sharing, and collaborative innovation ability only had a direct influence, while the incentive mechanism played only an indirect role. Finally, three suggestions were put forward on the idea of high-quality, sustainable development.

Keywords: collaborative innovation project; sustainable development; project performance; influencing factors; SEM

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1. Introduction

University–industry cooperation (UIC) first appeared in the Chinese Government Work Statement (GOV.CN WS) in 1999, and it was adjusted to university–industry cooperation innovation (UICI) in 2014. To date, 17 years' worth of data has been reported in the GOV.CN WS, which clearly shows that we should pay attention to it. From the time, frequency, and subsequent changes of words appearing in the GOV.CN WS, we can generally judge the trend of China's economic development pattern and its importance and evolution in national economic and social development. China has entered a new stage of promoting sustainable and high-quality development. At the microlevel, sustainable and high-quality development relies on innovation to enhance the vitality and competitiveness of economic entities and ensure the significant improvement of economic efficiency [1].

According to the bulletin of China's national economic and social statistics, the turnover of granted patents and technology contracts in China increased by 31.9 and 35.32 times, respectively, in the 20 years from 2001 to 2020 [2]. The collaborative innovation of UIC is one of the main forms of the transformation of scientific and technological achievements in the country, which is also the key to radical innovation in firms [3]. The UIC has developed vigorously in practice. Therefore, it is imperative to promote its development towards being of high quality.

The organization of UICI is achieved through the university–industry collaborative innovation project (UICIP). A collaborative innovation project (CIP) is a kind of project in which enterprises cooperate with universities, research institutes, and other enterprises to develop new technologies and processes [4]. In addition to the main form of the UICIP, there are also different forms of cooperation between universities and colleges, universities

and research institutes, and enterprises and enterprises. Wu et al. [5] described cooperative innovation projects as specific projects in which companies and public research institutions or other companies cooperate to create new technologies, products, materials, systems, or manufacturing processes.

The environment of science and technology innovation in China and abroad is changing rapidly and is complex. This will lead to increased uncertainty about the sustainable development of CIP. Therefore, how to ensure the sustainable development of CIPs and how to improve their performance are worthy of further study. In the past, most studies have focused on the impact of a single factor on collaborative innovation performance. These studies on single or few factors are of great significance to understand some problems of performance factors. However, they cannot be extended to a comprehensive and systematic analysis. Hence, there is a lack of systematic and comprehensive research on the influencing factors of performance. This study makes up for this deficiency by comprehensively and systematically investigating these factors to ensure the sustainable development of CIP and improve its performance. Specifically, the main contents and structure of this manuscript are as follows. A literature review is given in Section 2. The research hypotheses and conceptual model are presented in Section 3. The research design is described in Section 4. An empirical study using structural equation model hypothesis testing is described in Section 5. The conclusion and future work are presented in Section 6.

2. Literature Review

UIC may be the most important strategic instrument used to increase the efficiency and effectiveness of industrial investments in R&D, and increasing use makes it more important to figure out the factors that influence its performance [6]. After searching the existing relevant literature, we found that research on the influencing factors of collaborative innovation project performance mainly focuses on two aspects.

2.1. Literature Review on Tangible Influencing Factors of Collaborative Innovation Project Performance (CIPP)

One aspect of collaborative innovation project performance is focused on tangible factors.

López [7] conducted a study based on data collected through semi-structured interviews between January and October 2009, with a sample of 375 firms in three countries, that indicated that different companies have different innovation capabilities, and more innovative firms tend to be more interested in collaborating with universities. At the same time, high-tech and non-high-tech firms have different attitudes and intentions around collaborating with universities. Kafouros et al.'s [8] research showed that absorptive capacity has a significant impact on innovation performance, but the degrees of significance are different in different cooperative relationships.

Azagracaro et al.'s [9] research showed that innovation capability is affected by the relationship and cooperation mode of collaborative innovation project subjects. He et al.'s [10] research noted that characterizing leadership is important for revealing the interaction pattern and organizational structure through research collaboration. Fernandes et al. [11] showed that leadership support is important for the sustainable development of UIC. Benefits are key for university–industry collaborative innovation to maintain a long-term stable relationship [12], while benefit distribution positively affects the performance of collaborative innovation and can improve efficiency by influencing the incentive mechanism [12]. At the same time, the most critical factors for the realization of benefits are strategic, inter-relational, and cultural factors [13].

From the above analysis, we can see that research on the tangible influencing factors of collaborative innovation project performance mainly focuses on collaborative innovation ability, willingness to cooperate, leadership support, benefit creation, and benefit distribution.

2.2. Literature Review on Intangible Influencing Factors of Collaborative Innovation Project Performance (CIPP)

The other aspect of collaborative innovation project performance is focused on intangible factors.

Freitas [14] relied on in-depth data on 30 university–industry collaborations in the Netherlands and provided preliminary evidence that effective cooperation in UICs can create institutional incentives by targeting different individual motivations. Maurer [15] found that trust between project team members working on an inter-organizational project positively impacts the acquisition of external knowledge, which, in turn, promotes product innovation. Both universities and industries in the process of UIC need to overcome high cultural and organizational barriers in order to realize their potential [16].

Managers may engage in a social process of communication, both formal and informal [17], to engender trust between partners, and communication can also reduce the negative effects of information asymmetry in alliances [14]. Wu [18] studied cooperative knowledge transfer and governance mechanisms with regard to how to influence cooperative innovation performance using a sample of 238 projects with SEM. Using firm-level data on 263 firms in Korea, Han [19] found that knowledge sharing in UICs is likely related to the managerial strategies of CEOs rather than other team members.

Knowledge sharing in UICs has different effects on innovation performance through forming different areas [20], where it presents a core–edge spatial pattern [6]. Based on a historical analysis of UICs in Japan, Lee et al. [21] found that different types of UICs require functional specialization in boundary-spanning organizations by developing coordinative expertise, human resources, institutional arrangements, and organizational structures. When a university is heavily reliant on industry funding, it leads to the close co-evolution of UICs, thereby raising the risk of a mutual lock-in regarding specific technologies, which is good for collaborative innovation project performance [22].

From the above analysis, we can see that research on the intangible influencing factors of collaborative innovation project performance mainly focuses on incentive systems, the organizational atmosphere, effective communication, knowledge transfer, knowledge absorption, and resource dependence.

The above studies are very helpful for understanding and improving collaborative innovation project performance. However, all of them have investigated the influencing factors from a single perspective; as such, there is a lack of comprehensive and systematic research on the influencing factors. This study intends to make up for this deficiency. It summarizes the typical tangible and intangible factors that affect the performance of collaborative innovation projects and conducts comprehensive and systematic research.

Specifically, this study explores the specific impact mechanism of nine factors on the performance of collaborative innovation projects based on existing research. It includes four typical tangible factors (collaborative innovation ability, leadership support, incentive mechanism, and benefit distribution) and five typical intangible factors (knowledge sharing degree, effective communication, collaborative innovation willingness, resource dependence, and organizational climate). It also puts forward hypotheses on influencing factors and collaborative innovation project performance by using SEM to do empirical research with data from a questionnaire survey. Obviously, this study has important theoretical and practical significance toward deepening the research on the factors that impact collaborative innovation project performance.

3. Research Hypotheses and Conceptual Model

Based on the collaborative innovation project process and the existing literature, this paper summarizes the influencing factors as tangible and intangible factors. The tangible factors are collaborative innovation ability, leadership support, incentive mechanism, and benefit distribution. The intangible factors are knowledge sharing, effective communication, collaborative innovation willingness, resource dependence, and organizational climate.

According to the relevant research and the influence path characteristics of various factors with regard to project performance, these factors can be divided into those with a direct impact, indirect impact, and a combination of the two. The details are as follows.

3.1. Collaborative Innovation Project Performance (CIPP)

The Project Management Institute (PMI) claims that project success should balance the competitive demand for project quality, scope, time, and cost; address the different concerns; and meet the expectations of project stakeholders [23]. This is to satisfy the stakeholders. For collaborative innovation projects, project stakeholders are the main body of collaborative innovation.

In short, the connotation of project performance includes the overall satisfaction of collaborative innovation, quality performance, and cost performance of the results.

3.2. Influencing Factors and CIPP

3.2.1. Collaborative Innovation Ability and CIPP

Innovation ability is an important criterion for measuring the comprehensive competitiveness of a country or region [24]. Collaborative innovation capability is the foundation of collaborative innovation projects. Different subjects will have different innovation choices based on their own collaborative innovation capabilities [7]. Collaborative innovation ability is the key to success for complex cross-level, cross-sectoral, and cross-regional projects and can significantly improve the overall capacity of inter-subject collaboration [25]. Hong [26] found that absorptive capacity has a significant positive effect on innovation performance. Zhang [27] studied how to improve collaborative innovation ability and pointed out that providing support in terms of funds, policies, and so on could promote the improvement of such capabilities. Collaborative innovation capability has a significant impact on collaborative innovation performance [28]. Tseng [29] analyzed influential factors and concluded that an enterprise's technology ability has a direct impact on its cooperative innovation performance, showing that there is a positive correlation between the absorptive capacity of internal R&D and project performance. Since the performance of collaborative innovation projects mainly includes innovation performance [30], we propose the following hypothesis:

Hypothesis 1 (H1). *Project collaborative innovation ability has a significant positive correlation with the performance of collaborative innovation projects.*

3.2.2. Knowledge Sharing and CIPP

Collins and Smith [31] described knowledge sharing as access to knowledge innovation for teams, which is very important for improving innovation performance. Pang [32] did an empirical study with SEM, where the results showed that knowledge sharing can significantly affect the satisfaction of participants. Knowledge sharing has different sharing mechanisms in different teams [33]. Doan [34] empirically studied the relationship between knowledge sharing and innovation performance, where the results showed that both explicit and tacit knowledge sharing have a positive effect on firm performance. Rahmi [35] showed that cognitive diversity has a significant association with knowledge sharing, and knowledge sharing is positively associated with team innovation. Than's [36] study using 225 samples in Vietnam also showed that knowledge sharing, directly and indirectly, affects firm performance.

Therefore, we propose the following hypothesis:

Hypothesis 2 (H2). *Project knowledge sharing has a significant positive correlation with the performance of collaborative innovation projects.*

3.2.3. Leadership Support and CIPP

Pirola-Merlo [37] proposed that support from senior management is an important factor for the success of innovation activity. A survey of 289 project managers of public sector projects in Pakistan showed that project managers' leadership plays an important role in improving project performance. Leadership is embodied in schedule, cost, quality, and stakeholder satisfaction and is significantly related to the achievement of project performance [38]. Project research in Jordan showed that communication management, human resource management, time management, and risk management ability of project leaders have an impact on project performance [17]. Pham [39] studied the impact of leadership support on sustainable development performance. The results showed that leadership can affect performance by strengthening the relationship between environmental practice and sustainable development.

Therefore, we propose the following hypothesis:

Hypothesis 3 (H3). *Leadership support has a significant positive correlation with the performance of collaborative innovation projects.*

3.2.4. Effective Communication and CIPP

Kamuriwo [17] indicated that communication can reduce uncertainty in the process of cooperation, which is useful for ensuring the close relationship of cooperation and has positive significance for the realization of the organization. Bstieler [40] showed that the degree of trust between subjects can affect innovation performance by regulating communication and decision-making between them. Schreiner [41] showed that the closer the relationships are between all parties, the higher the cooperation performance. Adiguzel [42] showed that leadership effectiveness and learning orientation have a positive impact on effective communication, team creativity, and service innovation. Iswanti [43] showed that leaders' effective communication contributes to the development of an organizational innovation culture, and whether leaders can communicate effectively is influenced by leadership characteristics.

Therefore, we propose the following hypothesis:

Hypothesis 4 (H4). *Effective communication has a significant positive correlation with the performance of collaborative innovation projects.*

3.2.5. Incentive Mechanism and CIPP

Bruneel [44] noted that incentives were useful for motivating knowledge workers to share knowledge in order to improve the efficiency of knowledge innovation activities; otherwise, employees would keep the knowledge to themselves. He [45] employed the quantum game paradigm to study the incentive mechanism of industry–university–institute (IUI) collaborative innovation and found that a quantum strategy with maximal effort is the most profitable. Xiong [46] pointed out that it is very difficult for members to actively share knowledge of innovation failure without incentives, and this type of knowledge sharing plays an important role in reducing the probability of repeated failure and improving the innovation ability of virtual research organizations.

Wu [47] showed that different government incentive mechanisms have an impact on enterprises and universities. Government policy support is more attractive to enterprises, and financial support has a greater impact on universities.

Therefore, we propose the following hypothesis:

Hypothesis 5 (H5). *The incentive mechanism has a significant positive correlation with collaborative innovation intention.*

3.2.6. Collaborative Innovation Willingness and CIPP

Collaborative innovation willingness is a kind of driving factor that reflects the coordinators' emphasis on collaborative innovation and willingness. A study based on data collected from 375 companies in Spain, Portugal, and France through semi-structured interviews showed that more innovative enterprises tend to cooperate with universities. At the same time, national factors also affect the willingness of enterprises to cooperate with universities [7]. Vaaland [48] noted that in complex innovation projects, whether the cooperative intention of an external innovation source is positive or not will greatly affect innovation performance.

Gendreau [49] showed that collaborative innovation willingness and innovation ability can affect performance by influencing the knowledge absorptive capacity. The willingness to participate in cooperative innovation is positively influenced by organizational atmosphere and system design [50]. Members will show different levels of innovation willingness at different innovation stages [51]. The members of UICs have different levels of willingness to innovate. The willingness of enterprises is most easily affected by market behavior, while the willingness of universities is more easily affected by the willingness of the government [47].

Therefore, we propose the following hypotheses:

Hypothesis 6 (H6). *Collaborative innovation has a significant positive correlation with the performance of collaborative innovation projects.*

Hypothesis 7 (H7). *Collaborative innovation has a significant positive correlation with knowledge sharing.*

3.2.7. Resource Dependence and CIPP

The relationship between resource dependence and economically sustainable growth is U-shaped [52]. Resource dependence establishes the boundary of knowledge management, and good knowledge management ability is beneficial to organizational performance [53]. Nijhof [54] pointed out that cooperation must be established on the basis of mutual dependence. Narula [55] analyzed innovation cooperation in Japan and Europe and concluded that obtaining complementary knowledge was one of the most important goals to achieve when building government funding for innovation cooperation. Therefore, one of the motives for launching a collaborative innovation project is collaborative resource interdependence and the complementarity of economic activities among collaborative innovators. Moreover, when the parties are more desirous of scarce resources, they will be more willing to engage in collaborative innovation.

Therefore, we propose the following hypotheses:

Hypothesis 8 (H8). *Resource dependency has a significant positive correlation with collaborative innovation willingness.*

Hypothesis 9 (H9). *Resource dependency has a significant positive correlation with the performance of collaborative innovation projects.*

3.2.8. Benefit Distribution and CIPP

The pursuit of interests is the main goal of collaborators, but the pursuit of self-interest cannot be at the cost of damage to the interests of others; otherwise, it will lead to the failure of collaboration. In the process of collaborative innovation, the collaborative units invest their effort and should get corresponding returns. Sivadas [56] pointed out that the complexities of interest relations, the differences in organization unit goals, and the lack of a constraint mechanism will inevitably lead to a conflict of interest between organizations, which causes instability and failure. Establishing an appropriate and clear benefit distribution mechanism can guarantee successful collaborative innovation.

Berbegal [57] pointed out that effectively coordinating the distribution of interests is the key to guaranteeing a "win–win" scenario before launching innovation cooperation activities.

Li [58] showed that according to the different needs of alliance members, the benefit distribution model can fully encourage members to participate in collaborative innovation and improve project performance.

A reasonable distribution of interests will not only meet the needs of individuals but can also optimize the overall interests [59]. At the same time, it can also improve the willingness to innovate, which has a positive role in promoting environmental and economic development [60].

Therefore, we propose the following hypotheses:

Hypothesis 10 (H10). *Benefit distribution has a significant positive correlation with the willingness to engage in collaborative innovation.*

Hypothesis 11 (H11). *Benefit distribution has a significant positive correlation with the performance of collaborative innovation projects.*

3.2.9. Organizational Climate and CIPP

Collins [31] found that it was very important to create a team atmosphere with positive attitudes and knowledge sharing, which are important factors that affect knowledge sharing. Huang [61] argued that an environment of trust has a great role in promoting positive and spontaneous knowledge sharing. Steinmo [62] found that the innovation atmosphere of R&D teams has a very significant influence on the teams' innovation performance. Pirola [37] studied the impact of team climate on the speed of research and development project completion with a sample of 33 R&D teams and showed that team climate was significantly correlated with project performance. Xu [63] explored the influence of team innovation climate on individual and team innovation performance. The research showed that the team innovation climate can stimulate individual innovation intentions, which can benefit innovation performance. Rahmi [35] showed that team climate moderates the relationship between cognitive diversity and knowledge sharing.

Therefore, we propose the following hypotheses:

Hypothesis 12 (H12). *The organizational climate has a significant positive correlation with knowledge sharing.*

Hypothesis 13 (H13). *The organizational climate has a significant positive correlation with the performance of collaborative innovation projects.*

3.3. Conceptual Model

By dividing the influencing factors into tangible and intangible factors, this paper comprehensively and systematically discusses how these factors affect collaborative innovation project performance. Based on the above analysis, a conceptual model was established. Figure 1 shows the conceptual framework and theoretical relationships between the nine factors and collaborative innovation project performance.

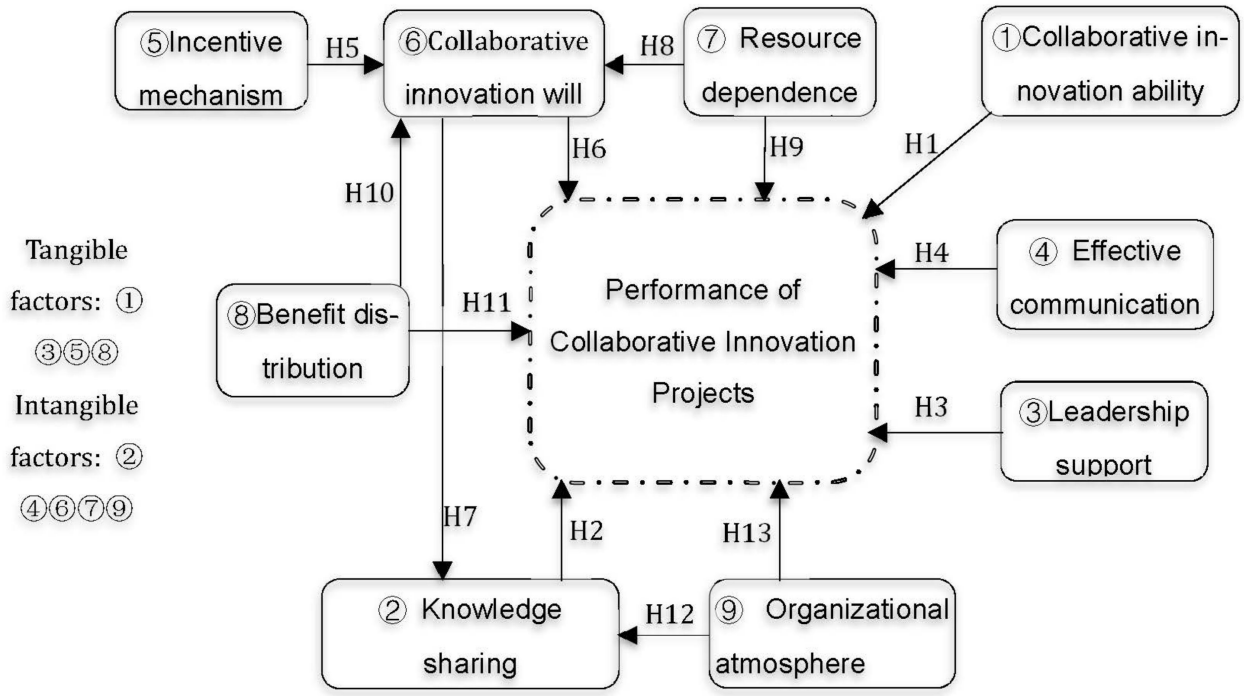

Figure 1. Conceptual framework.

4. Research Design

4.1. Questionnaire Design and Data Collection

For this study, we obtained the data needed for demonstration through a large-scale questionnaire survey. In the process of distributing the questionnaire, we tried to control the channel of distribution and screen the fillers in order to exclude the influence of external factors on the results.

The subjects of the questionnaire were individuals who were carrying out or had carried out collaborative innovation projects. Those who filled in the form were workers in government departments of science and technology, the R&D staff of enterprises, the scientific research staff at universities and research institutions, and the staff of a science and technology intermediary agency.

To distribute the questionnaire, we first implemented the survey in a digital format through the Questionnaire Star network platform (http://www.wjx.cn/jq/2761389.aspx) (accessed on 4 March 2021) and then sent it to those who met our requirements. A total of 290 questionnaires were sent out, 211 were returned, and 199 were filled out appropriately. The effective recovery rate was 68.6%.

The descriptive statistics of the characteristics of the sample projects are shown in Table 1 and Figure 2. These projects were relatively evenly distributed among provinces, occupations, academic disciplines, and works in the innovation research/working time, which could appropriately reflect the comprehensive situation of domestic collaborative innovation projects.

Table 1. Descriptive characteristics of respondents.

	Project Category	Number	Percentage
Occupation	Workers in government science and technology departments	24	12.06%
	Scientific researchers at colleges and universities	68	34.18%
	R&D personnel of enterprises	49	24.62%
	Researchers at research institutes	37	18.59%
	Personnel of science and technology intermediaries	21	10.55%
Educational background	Doctorate	57	28.64%
	Master's	75	37.69%
	Undergraduate	38	19.10%
	Junior college or below	29	14.57%
Length of relevant work	Within 1 year	18	9.03%
	1–3 years	78	39.20%
	3–5 years	39	19.60%
	5–10 years	30	15.08%
	More than 10 years	34	17.09%

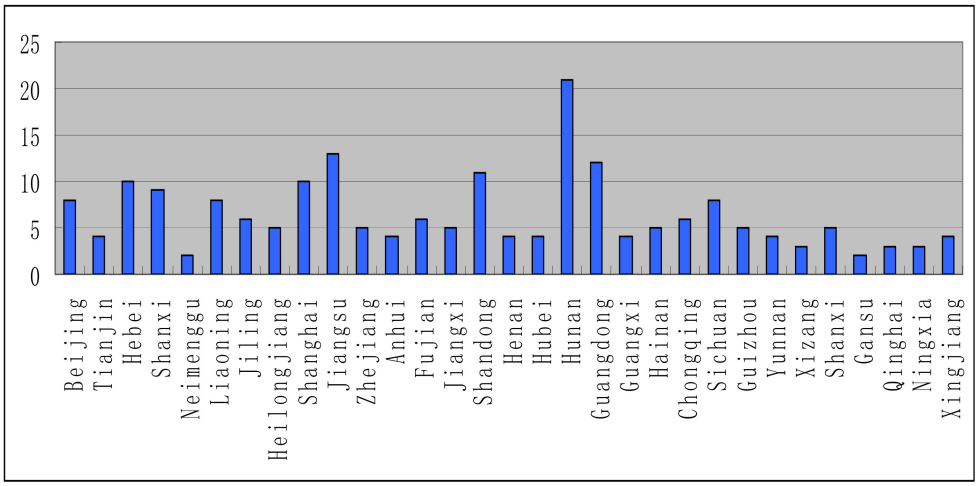

Figure 2. Province distribution of questionnaire respondents.

4.2. Variable Measurement

To meet the principle of representativeness and validity of research samples and to remain in line with the research theme, we referred to the mature scale and consulted experts and scholars in this field. According to the feedback from pilot interviews and a questionnaire survey, we produced the final questionnaire. The specific process was as follows:

First, we read foreign literature to obtain the relevant variables.

Second, we asked government, university, research institution, and technology enterprise agency experts to add comments on the questionnaire design through field research.

Third, we formed an initial version of the questionnaire according to the suggestions from the relevant research experts.

Finally, we tested the questionnaire by using small-scale samples.

According to the testing results, we made improvements and formed the final questionnaire.

The final questionnaire used a 5-level Likert system, asking respondents to rank their answers as 1, 3, 5, 7, or 9 based on their actual condition. The items included collaborative innovation project performance and intangible and tangible factors.

The dependent and independent variables were as follows:

(1) The dependent variable was collaborative innovation project performance. Based on the relevant research [23], this study comprehensively measured such performance based on satisfaction of the subject, project quality performance, and cost performance.

(2) The independent variables were four tangible factors and five intangible factors. Based on the existing research, the four tangible factors were collaborative innovation ability [7], leadership support [8], incentive mechanism [46], and benefit distribution [56]. The five intangible factors were knowledge sharing [31], effective communication [17], collaborative innovation willingness [48], resource dependence [54], and organizational climate [31].

4.3. Research Method

This study explored the impact mechanism of various tangible and intangible factors on collaborative innovation project performance in order to verify the relationship between multiple independent variables (latent variables) and a dependent variable (latent variable). The structural equation model (SEM) method is a multivariate analysis method that is used to verify the relationship between one or more independent variables (latent variables) and one or more dependent variables (latent variables) and has the ability to deal with the unobservable hypothesis concepts in the model. Based on studies by Al-Refaie [64] and Wen [65], we used structural equation modeling to carry out the study. Using AMOS software to analyze the SEM, we could judge whether the original hypotheses were tenable and determine the specific relationships between variables through the overall fitness of the model, significance levels, path coefficients, and so on.

5. Empirical Study

5.1. Reliability and Validity Analysis

Using SPSS statistical software, we analyzed the reliability and validity of the questionnaire with Cronbach's alpha and KMO factor analysis, respectively; the Cronbach's alpha values for each variable were greater than 0.7, indicating good reliability, while the KMO values were higher than 0.6, indicating high validity (Table 2).

Table 2. Reliability and validity of the questionnaire.

Factors	Observed Variables	Qid	Cronbach's α	KMO
Collaborative innovation	Collaborative body has a good ability for knowledge acquisition	SIC1	0.783	0.691
	Collaborative body has a good capacity for knowledge creation	SIC2		
	Collaborative body has a good ability to apply knowledge	SIC3		
Knowledge sharing	Wide sources of collaborative innovation knowledge	KSD1	0.739	0.745
	Rich in collaborative innovation knowledge	KSD2		
	Various forms of sharing collaborative innovation knowledge	KSD3		
	Multiple means of sharing collaborative innovation knowledge	KSD4		
Leadership support	Leader as director of collaborative innovation project	LS1	0.76	0.683
	Leader often visits and inspects collaborative innovation project	LS2		
	Leader prefers to give financial support to collaborative innovation project	LS3		

Table 2. *Cont.*

Factors	Observed Variables	Qid	Cronbach's α	KMO
Effective communication	Main staff members can maintain regular communication	EC1	0.721	0.781
	Main technical staff members regularly participate in meetings to deal with problems	EC2		
	Synergy between main regular formal meetings and formal document delivery	EC3		
	Synergy between main regular site visits and visits to other units	EC4		
Incentive mechanism	Diverse collaborative incentives with complementary level	EM1	0.832	0.618
	Collaborative incentives are implemented	EM2		
Collaborative innovation willingness	Main emphasis on collaboration and creating conditions for collaborative innovation	SIW1	0.806	0.652
	Main emphasis on collaboration and coordination involved in the collaborative innovation process	SIW2		
Resource dependence	Collaborative partners depend on their own valuable resources	RD1	0.743	0.695
	Collaborative partners depend on resources they cannot imitate	RD2		
	Collaborative partners can supplement their own resources	RD3		
Benefit distribution	Fair distribution of benefits	BD1	0.704	0.778
	Collaboration between diverse interests within the main distribution network	BD2		
	Coordinating bodies have clear self-interest and common interests	BD3		
	Coordinating bodies have formal distribution agreement(s)	BD4		
Organizational climate	Collaborative bodies can recognize and accept their differences	OC1	0.718	0.762
	Collaborative bodies agree to acquire knowledge of one another's value	OC2		
	Collaborative bodies trust each other to provide authentic information	OC3		
	Collaborative bodies can actively learn during the collaborative innovation process	OC4		
Collaborative innovation project performance	Collaborative bodies invest labor and funds and establish good infrastructural, cultural, and institutional environments	SCP1	0.735	0.786
	Collaborative bodies have good communication processes and cooperative practices	SCP2		
	Collaborative bodies have good collaborative innovation income	SCP3		
	Results of collaborative innovation projects have good economic and social impact	SCP4		

5.2. Common Method Bias

The data were from a questionnaire survey, which may lead to common method bias.

According to the research conclusion of Podsakoff [66], there are two ways to overcome and test common method bias: program control and statistical control.

In terms of procedure control, common method deviation was controlled in the questionnaire design and collection stage. This mainly included: (1) assuring that all the information collected would only be used for academic research, not for other purposes, and (2) repeatedly revising the items and wording of the questionnaire with reference

to the mature scale and in consultation with experienced experts in order to eliminate misunderstanding.

For statistical control, the Harman single-factor test was used. Harman univariate analysis was performed in the SPSS software. The result of the analysis showed that the explained percentage of the variance of the first common factor was 0.33, which is lower than the judgment standard of 0.50. Therefore, it can be considered that there was no obvious common method deviation in this study.

5.3. Hypothesis Testing Using a Structural Equation Model (SEM)

5.3.1. Model Fitting

This study used an SEM to verify the theoretical model with AMOS 17.0 software. There were 10 potential variables in the theoretical model: collaborative innovation, knowledge sharing, leadership support, effective communication, incentive mechanism, collaborative innovation willingness, resource dependence, benefit distribution, organizational climate, and collaborative innovation project performance. There were 33 observable variables: SIC1, SIC2, SIC3; KSD1, KSD2, KSD3, KSD4; LS1, LS2, LS3; EC1, EC2, EC3, EC4; EM1, EM2; SIW1, SIW2; RD1, RD2, RD3; BD1, BD2, BD3, BD4; OC1, OC2, OC3, OC4; and SCP1, SCP2, SCP3, SCP4. The specific content is shown in Figure 3.

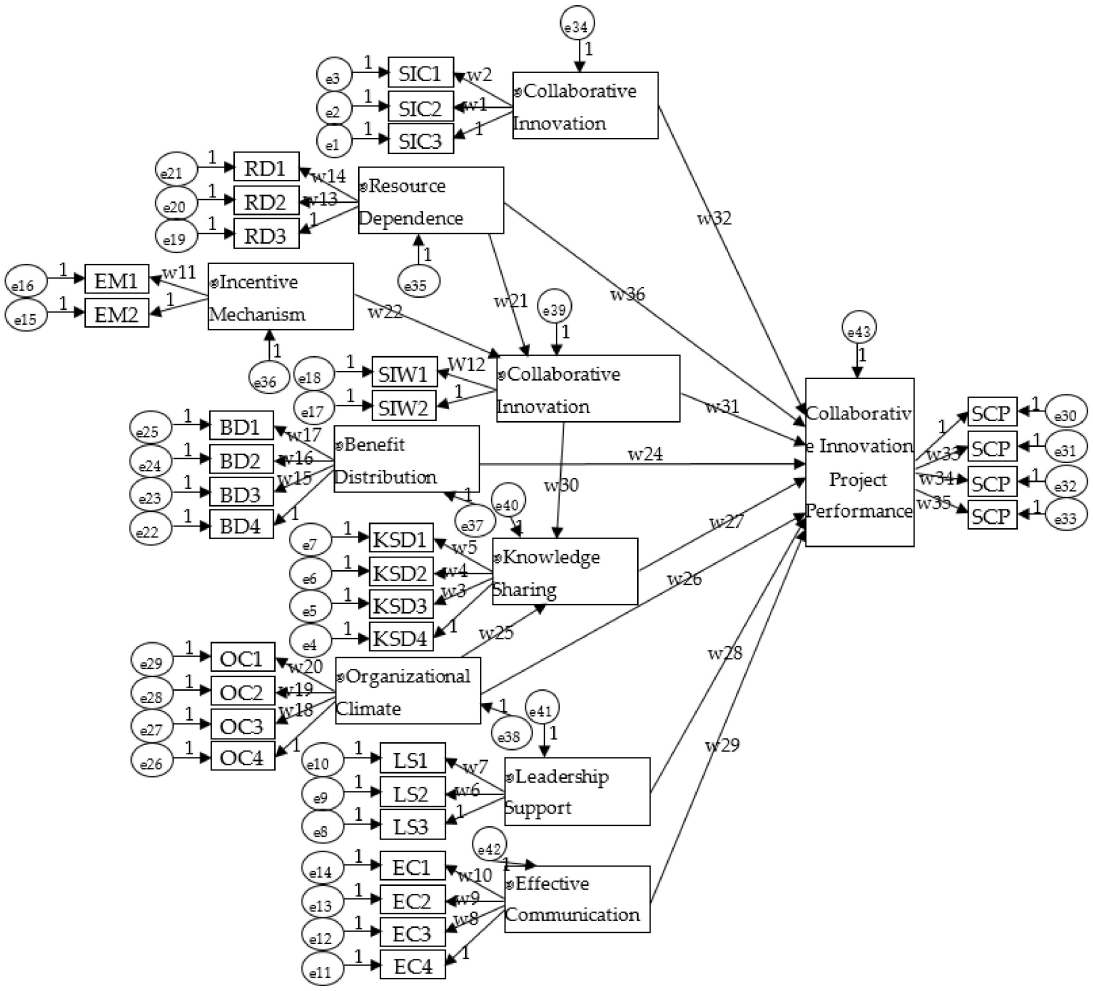

Figure 3. SEM of influencing factors of collaborative innovation project performance.

This study adopted the maximum likelihood method to estimate the model parameters with AMOS software, and the relevant results of the parameter estimation and fitting index of the model are shown in Table 3.

Table 3. Parameter estimation results.

			Estimate	S.E.	C.R.	*p*	Label
Collaborative innovation willingness	←	Resource dependence	0.199	0.034	5.783	***	W21
Collaborative innovation willingness	←	Incentive mechanism	0.237	0.03	7.944	***	W22
Collaborative innovation willingness	←	Benefit distribution	0.952	0.051	18.72	***	W23
Knowledge sharing	←	Organizational climate	1.269	0.169	7.486	***	W25
Knowledge sharing	←	Collaborative innovation willingness	0.022	0.009	2.415	0.016	W30
CIPP	←	Benefit distribution	0.545	0.027	20.013	***	W24
CIPP	←	Organizational climate	0.097	0.017	5.763	***	W26
CIPP	←	Knowledge sharing	0.093	0.016	5.886	***	W27
CIPP	←	Leadership support	0.129	0.01	12.272	***	W28
CIPP	←	Effective communication	0.213	0.028	7.658	***	W29
CIPP	←	Collaborative innovation willingness	0.143	0.015	9.515	***	W31
CIPP	←	Collaborative innovation	0.455	0.054	8.413	***	W32
CIPP	←	Resource dependence	0.045	0.013	3.357	***	W36

Note: *** It means significant at 1‰.

The results in the table are not standardized results. Table 4 shows the result of the standardized, intuitive parameter estimates and convenient parameters for size comparison.

Table 4. Parameter estimation results of standardized coefficients.

			Estimate
Collaborative innovation willingness	←	Resource dependence	0.777
Collaborative innovation willingness	←	Incentive mechanism	1.103
Collaborative innovation willingness	←	Benefit distribution	4.179
Knowledge sharing	←	Organizational climate	1.232
Knowledge sharing	←	Collaborative innovation willingness	0.007
CIPP	←	Benefit distribution	6.158
CIPP	←	Organizational climate	0.747
CIPP	←	Knowledge sharing	0.736
CIPP	←	Leadership support	1.651
CIPP	←	Effective communication	1.604
CIPP	←	Collaborative innovation willingness	0.368
CIPP	←	Collaborative innovation	4.052
CIPP	←	Resource dependence	0.45

From Tables 3 and 4, we can conclude that all parameters passed the inspection under the condition of a 5% significant level, which supports H1–H13.

To find the factors that affected the performance of collaborative innovation projects, we determined the total standardization coefficient that affected the performance, as shown in Table 5.

From Table 5, we can conclude that the influence of the distribution of interest factors was the largest among the nine factors affecting performance, and its total coefficient value was 7.716. The distribution of interest factors exerted an influence on the performance of collaborative innovation projects in three ways.

Table 5. Total impact of standardized coefficients.

	Collaborative Innovation Willingness	Knowledge Sharing	Collaborative Innovation Project Performance
Benefit distribution	4.179	0.03	7.716
Resource dependence	0.777	0.006	0.739
Incentive mechanism	1.103	0.008	0.411
Organizational climate	0	1.232	1.654
Collaborative innovation willingness	0	0.007	0.373
Effective communication	0	0	1.604
Leadership support	0	0	1.651
Knowledge sharing	0	0	0.736
Collaborative innovation	0	0	4.052
CIPP	0	0	0

First, the interest distribution directly affected the performance of collaborative innovation projects, and the coefficient was 6.158. Second, the interest distribution indirectly affected the performance by directly influencing the collaborative innovation willingness, and the coefficient was 4.179×0.368. Third, the interest distribution indirectly affected performance by directly influencing willingness and knowledge sharing, and the coefficient was $4.179 \times 0.007 \times 0.736$. The latter two were indirect effects.

The rest were similar; the dependence on resources had direct and indirect effects on the performance of collaborative innovation projects, and the total coefficient was 0.739; the incentive mechanism had an indirect influence on performance, and the coefficient was 0.411; organizational climate had direct and indirect effects on performance, and the total coefficient was 1.654; collaborative innovation willingness had direct and indirect effects on performance, and the total coefficient was 0.373; effective communication had a direct influence on performance, and the coefficient was 1.604; support from leadership had a direct influence on performance, and the coefficient was 1.651; knowledge sharing had a direct influence on performance, and the coefficient was 0.736; and collaborative innovation ability had a direct influence on performance, and the coefficient was 4.052.

5.3.2. Model Fitting Evaluation

This study distinguished the model fitting effect through the fitting degree of AMOS output indicators; Table 6 shows the main fitting indicators.

Table 6. Model fit index.

Fit Index	CMIN/DF	RMSEA	RMR	CFI	NFI	IFI
Results	2.238	0.072	0.034	0.924	0.912	0.928
Ideal standard	≤ 2	≤ 0.05	≤ 0.05	≥ 0.9	≥ 0.9	≥ 0.9
Evaluate	Acceptable	Acceptable	Good	Good	Good	Good

From Table 5, among the fitting indicators in SEM that affected the performance of collaborative innovation projects, the value of chi-square degrees of freedom was 2.238, which is slightly higher than the ideal value of 2; however, less than 3 is acceptable. The RMSEA value was 0.072, which is higher than the ideal value of 0.05, but values in the range of 0.05–0.08 are acceptable. The RMR value was 0.034, which is less than the ideal standard of 0.05. The other indices of CFI, NFI, and IFI were all higher than the ideal value of 0.9, indicating that the fitting degree of the model was good.

From the above analysis, we can conclude that the SEM fitting degree we established was good, which indicates that the construction of the whole model was effective.

6. Conclusions, Contributions, and Future Research

6.1. Conclusions and Theoretical Contributions

This study started from the perspective of collaborative innovation project performance and tried to outline the comprehensive and systematic action mechanism that affects performance. The factors that affect performance were divided into tangible and intangible elements, and a comprehensive model that included nine factors and collaborative innovation project performance was constructed. It also analyzed the specific influence mechanism, and an empirical study with a structural equation model was undertaken. The nine factors were interest distribution, resource dependence, incentive mechanism, organizational climate, collaborative innovation willingness, effective communication, leadership support, knowledge sharing degree, and collaborative innovation ability.

The research conclusion is not only helpful for deepening the related research on the impact of collaborative innovation project performance, it is also a useful supplement to the related theoretical research involving the nine elements and is helpful for boosting the practical needs of collaborative innovation project management.

Through theoretical analysis and empirical research, the main conclusions and theoretical contributions were as follows:

(1) The nine factors had a significant positive impact on the performance of collaborative innovation projects, where benefit distribution and collaborative innovation ability were the two most important factors.

In the SEM model with the nine factors of collaborative innovation project performance, the standardized path coefficients of benefit distribution, resource dependence, incentive mechanism, organizational climate, collaborative innovation willingness, effective communication, leadership support, knowledge sharing degree, and collaborative innovation ability on performance were 7.716, 0.739, 0.411, 1.654, 0.373, 1.604, 1.651, 0.736, and 4.052, respectively, and they were all significant.

This conclusion is similar to those of Berbegal [57], Shan [28], and Bstieler [40]. However, different from previous studies, this study combined tangible and intangible elements in a systematic and comprehensive analysis. The results further extend previous research and show that the performance of collaborative innovation projects is affected by both tangible and intangible elements. Therefore, the success of collaborative innovation projects depends on comprehensive and systematic management to a certain extent. It is an overall multidimensional arrangement, including the specific way of distributing interests and intangible elements, such as the organizational atmosphere.

(2) Benefit distribution, resource dependence, organizational climate, and collaborative innovation affected the project performance not only directly but also indirectly by influencing other factors.

The direct path coefficient of benefit distribution in project performance was 7.716, the indirect path coefficient in collaborative innovation willingness was 4.179×0.368, and the indirect path coefficient in collaborative innovation–willingness–knowledge sharing degree on project performance was $4.179 \times 0.007 \times 0.736$.

This shows that the influencing factors of project performance, in addition to having a direct role, also played an indirect role. It shows that when carrying out collaborative innovation projects, we should pay attention not only to the direct role of factors but also to the corresponding indirect role path.

This conclusion is similar to those of Gendreau [49], Yorusaf [53], and Liu [60]. The difference is that most of the conclusions in the previous studies were about the direct and indirect effects of certain factors on performance. This present result was based on the consideration of the impact of multiple factors on project performance and identified that some have a direct impact, some have an indirect impact, and some have both. This shows that the paths of factors in project performance were not the same, but each had its own specific trajectory.

(3) The incentive mechanism had no direct effect on project performance but indirectly affected project performance by influencing collaborative innovation willingness. Collabo-

rative innovation willingness affected project performance directly, as well as indirectly, through knowledge sharing. At the same time, it was affected by the incentive mechanism and resource dependence.

This shows that the influencing factors of collaborative innovation projects not only affected project performance but also had interaction paths with each other. This conclusion is an extension of the previous single study. It shows that the boundaries of different elements in the mechanism of collaborative innovation project performance are different.

The above conclusion is more applicable to China because it is based on China's CIP. If it is used in the field of CIP in other countries, appropriate adjustments should be made according to the specific situation.

6.2. Management Contribution

Against the background of sustainable and high-quality development, considering the practical needs of collaborative innovation project management, this paper puts forward the following suggestions:

(1) Establish a comprehensive and systematic management concept.

This study examined the impact of nine factors on collaborative innovation project performance: benefit allocation, resource dependence, incentive mechanism, organizational climate, collaborative innovation willingness, effective communication, leadership support, knowledge sharing degree, and collaborative innovation ability. The results show that these nine factors have a significant positive impact on performance.

These nine aspects involve the environment, atmosphere, resources, system, leadership, and so on, and include both tangible and intangible elements.

This shows that it is necessary to establish a comprehensive and systematic management concept for collaborative innovation project management. At the beginning of the project, there should be an effort to consider all aspects and formulate corresponding coping strategies. During the project, managers should assess the actual situation in order to dynamically adjust the management strategy.

(2) Use targeted management strategies.

The results also show that some factors affect project performance not only directly but also indirectly by influencing other factors. For example, benefit distribution had a direct impact on project performance, an indirect impact by influencing collaborative innovation willingness, and an indirect impact by influencing knowledge sharing degree by influencing collaborative innovation willingness. In addition, resource dependence, organizational climate, and collaborative innovation willingness had both direct and indirect effects on project performance.

This shows that collaborative innovation project management should use a more refined management strategy. It is necessary to implement specific and targeted management strategies in combination with different specific elements and consider their paths to the results.

(3) Form a balanced management pattern.

From the results, we can see that nine factors had a significant impact on performance, but their impact mechanisms were not the same. Some factors only had a direct impact on performance, some only had an indirect impact, some had both, and there was a certain degree of mechanism between the factors. That is, some factors could play an independent role, and some factors needed to be combined with others to enhance their role. This is a kind of balanced and dynamic thinking. Therefore, in the management of collaborative innovation projects, we must form a balanced management idea and pattern to produce the best benefit.

6.3. Research Limitations and Prospects

From a theoretical perspective, this study was based on related research, and the conclusion contributes to research on collaborative innovation projects and the nine influencing factors and can enrich the theoretical literature in the corresponding fields.

In practice, this study carried out an empirical analysis based on a certain number of collaborative innovation projects. The management suggestions based on the conclusions can boost the high-quality management needs of collaborative innovation projects.

At the same time, the study also has some limitations and prospects.

(1) The final effective sample data used in this study was taken from 199 collaborative innovation projects; this involved many regional industries. However, in practice, the scale of such projects is huge, so it is still worth expanding the sample size for further research.

(2) The sample of this study was only from China, and subjects from different countries may have different experiences [67]. Therefore, in the future, the conclusions could be applied to other countries with different cultural backgrounds, which will verify whether our conclusions can be supported.

(3) In practice, a collaborative innovation project is a complex and diverse dynamic process. If the project performance variables can be set as dynamic variables to carry out research, it will be more reasonable in theory and more in line with the characteristics of such projects in practice.

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Impact of Entrepreneurial Leadership on Product Innovation Performance: Intervening Effect of Absorptive Capacity, Intra-Firm Networks, and Design Thinking

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Abstract: The main objective of this research is to investigate the nexus between entrepreneurial leadership and product innovation performance. In addition, the mediating mechanism of absorptive capacity, intra-firm networks, and design thinking through which entrepreneurial leaders influence product innovation performanceis also studied. The researcher contacted three hundred (300) plus firms; 157 firms showed a willingness to participate, and 96 firms provided the data with a response rate of 61.15%. Out of those 96 firms, the data from 71 firms were used for the final analysis, yielding an effective response rate of 45.22%. Only middle and top-level employees from the marketing and research & development departments from Pakistani firms were selected as respondents because these two departments are directly related to product innovation performance. To test the hypothesis, the Smart PLS-SEM technique wasused. The empirical analysis revealed that entrepreneurial leadership impacted product innovation performance through the mediating mechanism of design thinking, intra-firm networks, and absorptive capacity. The current research contributes to entrepreneurial leadership theory by proposing and empirically testing how entrepreneurial leaders affect product innovation performance.

Keywords: entrepreneurial leadership; product innovation performance; risk; design thinking; intra-firm networks; absorptive capacity

1. Introduction

Recently, the importance of product innovation performance has increased manifold due to globalization, technological advancements, and the shortening of product life cycles. The purpose of this paper is to investigate the impact of the entrepreneurial leadership functional mechanism on the product innovation performance of firms. To achieve the objective, two research questions were formed: What is the connection between entrepreneurial leadership and product innovation performance? How doesthe mechanism of design thinking, intra-firm networks, and absorptive capacity help entrepreneurial leaders to improve and influence product innovation performance?

This study, however, studied product innovation performance from the perspective of entrepreneurial leadership and its mechanism, which is comprised of the intra-firm networks, design thinking, and absorptive capacity.

The role of entrepreneurship and leadership is studied by many scholars in relation to product innovation performance and the creation of an ecosystem for innovation. Joseph A Schumpeter [1] and the OECD [2] acknowledge leadership and entrepreneurship as main drivers for innovation. Traditionally, these two concepts are discussed separately in the literature; however, Thornberry (2007) synergized these concepts together and presented his famous entrepreneurial leadership theory with five distinct dimensions of entrepreneurial leadership. These are discussed in Sections 2 and 3. Entrepreneurial leadership is at the crossroad of leadership and entrepreneurship and is about exploring an opportunity and then pushing others to collaborate for the exploitation of the opportunity by creating an environment conducive for innovation.

Previous studies have mainly examined the relationship between entrepreneurial leadership and innovation performance from the perspective of idea generation and diffusion, personal qualities, and other behavioral and psychological aspects of entrepreneurial leadership [3], overlooking the functional mechanism and tools through which entrepreneurial leadership affects innovation performance. Entrepreneurial leadership is all about creating a "climate" suitable for innovation that works through the mechanism of collaboration, problem-solving thinking, and knowledge management [4]. Previous studies have been unable to explore the mechanism through which entrepreneurial leadership influences the innovation performance. The current research proposes and empirically teststhe mediating functional mechanism of design thinking, intra-firm networks, and absorptive capacity.

Significance of the Study

The present study suggests a functional mechanism in the form of networking and design thinking through which entrepreneurial leadership affects product innovation performance. Furthermore, the present study suggests the use of design thinking as a tool for pro-active and problem-solving thinking, which is one of the main attributes of entrepreneurial leadership [5]. In addition to this, the current study also has some profound contributions; first, it proposes and empirically tests a mechanism through which entrepreneurial leadership affects product innovation. Second, it proposes a tool of design thinking to complement the pro-active and problem-solving characteristics of entrepreneurial leadership, hence contributing to the theory of entrepreneurial leadership by synergizing it with the theory of design thinking.

2. Literature Review and Theoretical Framework

2.1. Product Innovation Performance

Joseph A. Schumpeter and the Organization for Economic Cooperation and Development (OECD) have highlighted that innovation and entrepreneurship are the main strategic stimuli behind competitive advantage and economic development [1]. Chryssochoidis [6] is of the view that product innovation performance is the prime manifestation of innovation inan organization and plays a critical role in improving the competitiveness and the competitive advantage of the organization, thus ensuring economic development. Product life cycles are getting shorter; out of the box thinking is called for to improve the product innovation performance for rapid product development and commercialization [7].

The difference between product innovation and product innovation performance is obvious. Product innovation refers to "the introduction of goods and services that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvement in technical specifications, components, and materials, incorporated software, user-friendliness or other functional characteristics". Product innovation performance refers to the "firm's effectiveness and efficiency in new product development measured as the extent to which the firm has achieved its market share and profitability objective" [8]. Product innovation performance is an outcome of successful

knowledge exploitation and includes different technical and non-technical aspects starting from research and development to design, and the management of the manufacturing process to commercial activities that include the marketing of new or improved products [9].

Product innovation performance consists of two very important and complementary dimensions: product innovation efficiency and product innovation efficacy. Product innovation efficacy represents the degree of success whereas product innovation efficiency represents the efforts spent (time, resources, etc.) to achieve a certain degree of success. Product innovation performance starts with discovery (idea generation) and ends with implementation (commercial activities) [10]. Besides effectiveness and efficiency, another important element of product innovation performance is implementation. A new or significantly improved product (good or service) is considered as implemented when they are offered to actual or potential users in the real environment [11].

2.2. Entrepreneurial Leadership

Leadership and entrepreneurship are considered as the main drivers for innovation; traditionally these two concepts have been discussed separately in the literature, however, both concepts can be synergized together by combining the characteristics of transformational, transactional, and charismatic leadership with the DNA and IQ of entrepreneurship [12]. Thornberry [13] has presented the theory of entrepreneurial leadership by highlighting five distinct dimensions that are discussed in the following paragraph.

General entrepreneurial leadership behavior (GELB) is all about creating an environment conducive for innovation where followers can feel motivated to innovate and where their innovation accomplishments are recognized and acknowledged. Explorer behavior (EXPB) is an entrepreneurial leader's ability to explore the opportunities around him and to exploit them by pushing the organizational limits of innovation and creativity. Miner behavior (MINB) on the other hand relates to the entrepreneurial leader's ability to create a sustainable competitive advantage for their organization by introducing and applying new innovative approaches and techniques to people, processes, and procedures. Furthermore, the accelerated behavior (ACCB) of entrepreneurial leaders is aimed at creating an innovative environment for others by using the skills of pro-active and problem-solving thinking, thus accelerating the process of innovation. Finally, the integrated behavior (INTB) of entrepreneurial leaders means the application of the inherent innovative and creative thinking mindset of entrepreneurial leaders across the organization through effective communication and coordination [14].

Pisapi [5] also focused on entrepreneurial leadership that is at the crossroad of leadership and entrepreneurship and is all about seeking opportunities and then pushing others to collaborate for opportunity exploitation by creating an environment conducive for innovation and knowledge sharing. Gupta [15] further explained that entrepreneurial leadership theory is all about fusing leadership with the concepts of entrepreneurship, entrepreneurial orientation, and entrepreneurial management. Esmer [16] defined entrepreneurial leadership as a function of leadership and entrepreneurship in equation form as Entrepreneurial Leadership = f (Entrepreneurship, Leadership).

2.3. Design Thinking

The OECD [2] stressed the fact that innovation should be user-centered and implementable. Several previous studies have also highlighted the importance of the user/human centeredness of innovation and the need for creative problem-solving thinking to foster innovation [17]. Design thinking theory states that thinking like a designer is the most effective creative problem-solving approach for complex problems and the outcome of the design thinking would be a user/human-centered product [18]. Design thinking acts as a bridge between the innovation ecosystem and the corporate strategy of the firm, resulting in innovations that are at a par with the needs of the era of IoT and industry 4.0 and 5.0 [19].

Tim Brown described design thinking as a discipline that uses the designer's sensibility and methods to match people's needs as to what is technologically feasible and what a

viable business strategy can convert into customer value and market opportunity [20]. Design thinking is "bringing innovation to the market by converting learning from users into viable business outcomes" [21]. As a result, companies can expect to obtain more "desirable solutions" that offer "creative alternatives" which go "beyond esthetics" and are "sophisticated experiences" that are "emotionally satisfying and meaningful" as well as a "combination of product, services, spaces and information". Corporate entrepreneurship, from where the concept of entrepreneurial leadership emerges, works through design thinking; this relates to opportunity recognition, effectuation, the intersection of design thinking and entrepreneurship strategy, and entrepreneurial design management [22].

2.4. Intra-Firm Networks

Intra-firm networks refer to the intensity of the interactions among functional units of an organization. More explicitly, intra-firm networks are about internal networks formed by the functional areas e.g., R&D, manufacturing, marketing, etc. of the firm. Although knowledge is available in the literature on the relationship between innovation performance and intra-firm networks, little has been discussed in relation to how firms can organize intra-firm networks to obtain the maximum out of the innovation potential hidden in intra-firm networks. It is a well-established fact that individuals and organizational mechanisms that formintra-firm networks support knowledge management, i.e., knowledge creation, transformation, sharing, and diffusion to boost the innovation performance of firms. Organizational practices and mechanisms encouraging networking between individuals (resulting in cross-functional networking) can be both formal and informal, which has recently been attracting more attention from scholars and practitioners [23].

Khoja [24] has further stated that intra-firm networks enhance a firm's intellectual capital, i.e., a firm's knowledge ability and knowing capabilities. They define intra-firm networks as a "set of formal and/or informal relationships among business units of the same legal entity" adopted from Ravi S Achrol and Philip Kotler [25]. Under this arrangement, each functional unit has considerable freedom in making its decisions concerning resource allocation while working in close collaboration with affiliated functional units.

The previous literature on intra-firm networks has mainly focused on three types of ties based on different types of communication i.e., task-related communication, advice related communication, and social communication. Other types of ties may include friendship, exchange, collaboration, and spatial closeness. Moreover, intra-firm networks also include formal and informal communication, and informational flow between both hierarchal layers and among individuals from different functional subunits of the organization. Furthermore, intra-firm collaboration is the essence of intra-firm networks, based on the urge to exchange different views, skills, and expertise possessed by individuals belonging to different functional units [26]. Another study concluded that intra-firm networks mean that organizations are networks of individuals that all have their specific characteristics, and that intra-firm networks are comprised of individuals, cross-functional teams and/or business/functional units that are connected through formal organizational structures and hierarchies or informal personal relations [27].

2.5. Absorptive Capacity

Lichtenthaler [28] has explained that the absorptive capacity of the firm translates the flow of information into something valuable for the organization and it indirectly improves the innovation performance of the organization. He defines absorptive capacity as "an ability to recognize the value of new information, assimilate it, and apply it in commercial ends". Zahra [29] has presented a comprehensive definition of ACAP, stating, "ACAP requires learning capability and develops problem-solving skills; learning capability is the capacity to assimilate knowledge for imitation and problem-solving skills to create new knowledge-for innovation". Social exchange theory plays an important role in creating a conducive environment for organizational learning by knowledge accumulation and

diffusion within the firm, and absorptive capacity increases social exchange within the firm, thus enhancing organizational learning [30].

2.6. Hypothesis Development

Swiercz [31] has explained the relationship between entrepreneurial leadership and innovation performance, stating that entrepreneurial leadership positively influences the innovation performance of the firm. Swiercz explained the role of entrepreneurial leadership in the firm's innovation performance by stating that entrepreneurial leadership positively affects creativity and innovation. Furthermore, Mamun [32] has explained the relationship between entrepreneurial leadership, a firm's innovation performance, and its sustainability. Previous studies related to the impact of entrepreneurial leadership on innovation performance established the relationship between entrepreneurial leadership and innovation performance; however, little work has been conducted to assess the impact of entrepreneurial leadership on the product innovation performance of the firms, and therefore, building on this premise the following was postulated [33].

Hypothesis 1 (H1). *Entrepreneurial Leadership has a positive relationship with product innovation performance (PIP*).

The theory of entrepreneurial leadership (EL) by the authors of [34] highlighted an important dimension of EL, i.e., integrated behavior (INTB) which means the application of an inherent innovative and creative thinking mindset of entrepreneurial leaders across the organization through effective communication and coordination. Similarly, different previous studies have highlighted the collaborative dimension of EL; however, they have mainly examined the relationship between entrepreneurial leadership and the innovation performance of the firm from the perspective of idea generation and diffusion, the personal qualities of entrepreneurial leaders and other behavioral and psychological aspects of entrepreneurial leadership, hence overlooking the functional mechanism of entrepreneurial leadership and its effect on the innovation performance of the firms. Entrepreneurial leadership is all about creating a "climate" suitable for innovation and one important aspect of this climate is collaboration within organizational units [35]. Furthermore, an important characteristic of entrepreneurial leadership of a collaborative nature is that it that promotes knowledge acquisition and diffusion. Entrepreneurial leadership has a positive relationship with social capital whichis the result of collaboration and networking [36]. Therefore, based on the integrative behavior (INTB) dimension of EL theory and the collaborative nature of entrepreneurial leadership and its connection with building social capital through networking, the following hypothesis was developed.

Hypothesis 2a (H2a). *Entrepreneurial leadership (EL) has a positive relationship with the intra-firm network.*

The theory of EL [37] highlighted two important dimensions of EL i.e., miner behavior (MINB) and accelerated behavior (ACCB). MINB is all about the entrepreneurial leader's ability to create a sustainable competitive advantage for their organization by introducing and applying new innovative approaches and techniques to people, processes and procedures, whereas ACCB is aimed at creating an innovative environment for others by using the skills of pro-active and problem-solving thinking, thus accelerating the process of innovation. This builds on the notion that pro-activeness and problem-solving thinking are important functional characteristics of entrepreneurial leaders [38]. This present study suggests design thinking as a tool and technique for pro-activeness and problem-solving thinking. Therefore, building on the notions of the MINB and ACCB dimensions of theory of EL and the arguments in previous studies, the following hypothesis was formed.

Hypothesis 2b (H2b). *Entrepreneurial leadership has a positive relationship with design thinking*.

Explorer behavior (EXPB) is another important dimension of entrepreneurial leadership theory presented by the authors in [37]. It relates tothe entrepreneurial leader's ability to explore the opportunities around him and to exploit them by pushing the organizational limits of innovation and creativity, complementing the integrated behavior (INTB) dimension of entrepreneurial leadership that means the application of an inherent innovative and creative thinking mindset of entrepreneurial leaders across the organization through effective communication and coordination. The primary appeal and purpose of the EXPB and INTB dimensions of entrepreneurial leadership is knowledge accumulation and diffusion across the organization. It can be deduced from the EXPB and INTB dimensions that entrepreneurial leadership plays an important role in enhancing the absorptive capacity of the firm that relates to knowledge accumulation and diffusion.

Furthermore, several previous studies including [35,39] have highlighted that knowledge acquisition and diffusion are a few of the main characteristics of entrepreneurial leadership. Ferreras [40] has studied the relationship between transformational leadership and the firm's absorptive capacity and found this relationship to be positive. Thornberry explained in his theory of entrepreneurial leadership that entrepreneurial leaders have characteristics of transformational and charismatic leadership and the DNA and IQ of entrepreneurs; therefore, it can be inferred that the relationship between entrepreneurial leadership and absorptive capacity should be positive as it is between transformational leadership and absorptive capacity. Further building on the premise presented by Musa [41] that entrepreneurial leadership creates a climate and environment conducive for knowledge accumulation and diffusion to take place, we postulate the following.

Hypothesis 2c (H2c). *Entrepreneurial leadership has a positive relationship with absorptive capacity.*

As discussed earlier, the theory and model of EL highlighted two other very important dimensions of EL, i.e., miner behavior (MINB) and accelerated behavior (ACCB). MINB refers to the entrepreneurial leader's ability to create a sustainable competitive advantage for their organization by introducing and applying new innovative approaches and techniques to people, processes, and procedures, whereas ACCB is aimed at creating an innovative environment for others by using the skills of pro-active and problem-solving thinking, thus accelerating the process of innovation. It can be induced from the MINB and ACCB dimensions that entrepreneurial leaders are problem solvers through creative and pro-active thinking. They think of out of the box solutions and introduce a new mindset, tools, techniques, processes, and procedures within the organization. The MINB and ACCB dimensions of entrepreneurial leaders are essential elements that can solve the difficult problem of innovation [42].

The modern literature related to design thinking has been identified as the main force that is helping next-generation entrepreneurs to be more effective and innovative. It has been further stated that both design thinking and entrepreneurship work in conjunction and support each other to develop an ecosystem. Furthermore, it has been stated that leaders are encouraging the design thinking practices within organizations, which validates the assumption of the current study that entrepreneurial leaders encourage and stimulate design thinking practices within the organization [43]. Von [44] studied the interplay between entrepreneurship and design thinking and declared entrepreneurs as design managers, emphasizing the point that entrepreneurs do have design thinking attributes. The authors in [45] have further stressed that design thinking contributes to an organizational culture that fosters innovation performance, and that leadership and an entrepreneurial mindset play an important role in it.

Entrepreneurial leaders "frame the problem" using pro-active and problem-solving techniques for a better innovation performance. Similarly, the authors in [38] have highlighted four points of corporate entrepreneurship from where the concept of entrepreneurial leadership emerges and works through design thinking. These include opportunity recognition, effectuation, the intersection of design thinking, and entrepreneurship strategy and entrepreneurial design management. Although they highlighted the relationship

between corporate entrepreneurship and design thinking, we now know that the concept of entrepreneurial leadership emerges from corporate entrepreneurship and shares many common characteristics, such as the use of pro-active and problem-solving thinking for "framing the problem" in hand [45]. Based on this, it was hypothesized that similar to corporate entrepreneurs, entrepreneurial leaders also use the mechanism of design thinking to frame the problem in hand for a better innovation performance. Hence, the following hypothesis was formed.

Hypothesis 3 (H3). *Design thinking (DT) mediates the relationship between EL and PIP.*

Another important dimension of entrepreneurial leadership theory is integrator behavior (INTB) which means the application of the inherent innovative and creative thinking mindset of entrepreneurial leaders across the organization through effective communication and coordination. It can be deduced from the INTB dimension that entrepreneurial leadership encourages networking within an organizational structure. Entrepreneurial leaders not only indulge in networking across the functional units of the organization, but they also create a networking environment and encourage their team members to network across functional units. The primary appeal of this intra-firm networking is to speed up the process of idea generation and sharing to reduce the time for product innovation, thus improving the product innovation of the firm. Many previous studies have stated that intra-firm networking has a positive effect on both the radical and incremental innovation performance of the firm and is defined as the intensity of interaction among the functional units of an organization [46]. Entrepreneurial leadership is collaborative in nature and this characteristic is used for a better innovation performance. Based on the INTB dimension of entrepreneurial leadership theory and the collaborative nature of entrepreneurial leadership, it can be inferred that entrepreneurial leadership uses and works through the mechanism of an intra-firm network to positively influence the product innovation performance of the firm [47]. Therefore, it was postulated that entrepreneurial leadership positively influences the product innovation performance of the firm by using an intra-firm network. Hence, the following hypothesis was formed.

Hypothesis 4 (H4). *Intra-firm networks (INTRA) mediates the relationship between EL and PIP.*

Explorer behavior (EXPB) is another important dimension of entrepreneurial leadership theory. It refers to an entrepreneurial leader's ability to explore the opportunities around him and exploit them by pushing the organizational limits of innovation and creativity, complementing the integrated behavior (INTB) dimension of entrepreneurial leadership theory that means the application of an inherent innovative and creative thinking mindset of entrepreneurial leaders across the organization through effective communication and coordination. The primary appeal and purpose of the EXPB dimension of entrepreneurial leadership is knowledge accumulation and diffusion across the organization. The absorptive capacity of the firm translates the flow of information into something valuable for the organization and it indirectly improves the innovation performance of the organization. Absorptive capacity is defined as "an ability to recognize the value of new information, assimilate it, and apply it in commercial ends".

It has been further stated that the role of absorptive capacity must be viewed in relation to organizational learning theory, resource-based view theory, and dynamic capability theory. It can be inferred from previous studies that if knowledge is assimilated and absorbed properly it will become an intangible asset of the firm in the form of a shift in thinking approach [48]. Previous studies have highlighted the fact that the absorptive capacity of the firm helps to channel information from different sources and helps to improve the overall learning and hence the mindset of the organization [49]. Entrepreneursuse knowledge diffusion and dissemination techniques for better innovation performances, by spreading and absorbing new ideas across the organization. Therefore, as entrepreneurial leadership is at the crossroad of entrepreneurship and leadership and shares characteristics from both

domains, we can infer that entrepreneurial leaders also use the technique of absorptive capacity for knowledge diffusion and dissemination, hence we can postulate the following.

Hypothesis 5 (H5). *Absorptive capacity (ACAP) mediates the relationship between EL and PIP.*

On the basis of previous literature and hypothesis the researchers have proposed this theoretical framework (Figure 1) to be empirically tested and validated.

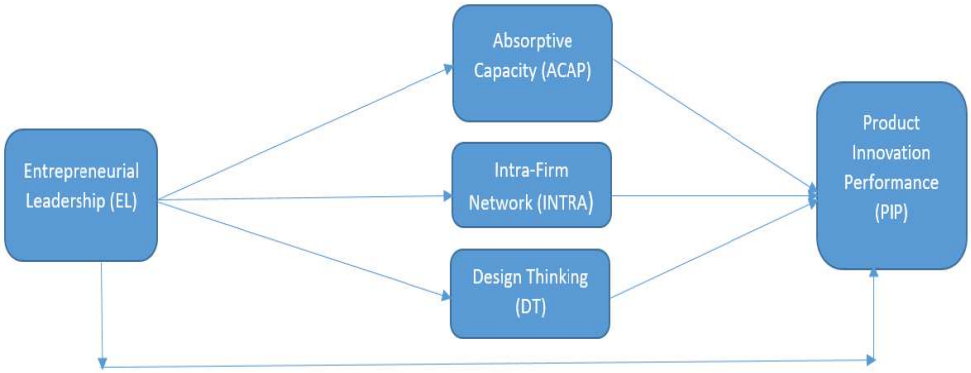

Figure 1. Theoretical Framework.

3. Materials and Methods

The middle and top-level managerial level employees from the Marketing and R&D departments from Pakistani firms were contacted for data collection. Respondents were selected from these two departments because they are directly related to product innovation performance, and thisis also in accordance with similar previous studies on product innovation performance [49]. Three hundred (300) plus firms were contacted, 157 firms showed a willingness to participate, and 96 firms provided the data, yielding a response rate of 61.15%. Out of those 96 firms, data from 71 firms (where 1 firm represented 1 team) were used for the final analysis, yielding an effective response rate of 45.22%. Three hundred and eighty (380) responses were included in the final data analysis from 71 firms (where 1 firm represented 1 team). A combination of convenience and purposive sampling was used to select firms from both the manufacturing and service sectors from the main industrial and commercial cities of Pakistan i.e., Karachi, Lahore, Islamabad, Faisalabad, Gujranwala, Gujrat, Sialkot, and Peshawar. Lists of these firms were obtained from the regulatory authorities i.e., the Securities and Exchange Commission of Pakistan (SECP), the Small and Medium Enterprises Development Authority (SMEDA), etc. A combination of self and email administrated data collection methods were used as self-administrative data collection methods to help increase the response rate and the authenticity of the results [50].

To collect the data, the current research useda previously validated questionnaire and the detail of each measurementis as follows. The measure for entrepreneurial leadership was adapted from [51] where the respondents were asked to rate their team leader or immediate manager on his/her entrepreneurial leadership abilities. The measure of collaborative intra-firm innovation networks was adapted from Schleimer [52]. The measure for design thinking was adapted from Blizzard [53]. The measure of absorptive capacity was adapted from Engelman [54]. The measure of product innovation performance was adapted from Muñoz-Pascual [10].

Our basic unit of analysis was a team, while we collected the data at the individual level. So, to reach one level, lower-level data (individual level) was aggregated to a higher level (team level). To justify the aggregation, the IRR (interrater reliability) and the IRA (inter-rater agreement) were calculated. A calculation of both the IRA and the IRA+IRR to justify the aggregation was preferred; we calculated the $r_{WG(j)}$ for IRR and ICC(1) and ICC(2) for IRA+IRR [3]. We calculated the $r_{WG\ (j),}$ ICC (1), and ICC (2) values using an Excel spreadsheet. $Ther_{WG(j)}$ values for all measures used in this study were greater than the

generally accepted cut-off value of 0.70 which shows greater agreement and justifies the aggregation of data. Similarly, the ICC (1) and ICC (2) values for all measures were greater than 0.70 which shows a large effect at the significance level of $p < 0.05$. After justifying all the statistical requirements for data aggregation, the data was aggregated using SPSS.

Smart PLS was mainly used for analyzing the data using PLS-SEM, as this technique was more suited for the predictive objective of the present study. PLS-SEM is basically a complete package of statistical analyses including reliability, validity, and hypotheses testing on the basics of regression, moderation, and mediation analysis. The current research used multiple mediators to understand the depth of the mechanism through which entrepreneurial leadership influenced the product innovation performance. The PLS-SEM technique has a better predictive power over the covariance-based SEM (CB-SEM) [55,56].

4. Results

The PLS-SEM analysis was performed in a two-step process following the guidelines of Hair [57]; initially, the measurement model was assessed for reliability and validity as per the prescribed criteria. After establishing the soundness of the measurement model, the structural model was assessed.

4.1. Measurement Model

4.1.1. Convergent Validity

To assess the convergent validity of the constructs, factor loading was calculated. A factor loading of 0.70 is considered as good; however, factor loading between 0.40 and 0.70 is also acceptable. Items with afactor loading of less than 0.4 should be removed from the analysis, however, items with afactor loading between 0.40 and 0.69 should only be considered for removal if their removal increases the average value extracted (AVE) and the composite reliability beyond the threshold limit of 0.50. All the factor loadings were above 0.70 except the factor loading of ACAP-1 (0.592).However, this item was also retained for analysis as the AVE was already greater than 0.50; thus, it was retained for the sake of content validity. To further establish the convergent validity, the AVE was calculated. To establish the strong convergent, AVE should be greater than 0.50 [56,57]. The results revealed that the AVE for ACAP, DT, EL, Intra-firm and PIP was 0.631, 0.718, 0.692, 0.618 and 0.584, respectively.

4.1.2. Internal Consistency Reliability

After establishing the convergent validity for the measurement model, in the next step, the internal consistency reliability was assessed. Two measures for internal consistency reliability were calculated: Cronbach alpha and composite reliability (CR). According to the authors in [58] Cronbach alpha has statistical shortcomings as it assumes that all indicators have an equal factor loading on the construct, so it is better to calculate the composite reliability. The analysis showed that the Cronbach alpha and CR for ACAP (0.876, 0.898), DT (0.868, 0.895), EL (0.852, 0.899), Intra-Firm (0.797, 0.866) and PIP (0.857, 0.894) were within the range of the acceptable threshold of 0.60 to 0.90 [57].

4.1.3. Discriminant Validity

After establishing the internal consistency reliability, the discriminant validity was assessed for the measurement model by using the Fornell-Larcker Criterion and HTMT. In the case of PLS-SEM, HTMT has more statistical power and is superior to the Fornell-Larcker criterion to assess the discriminant validity [59,60]. The results depicted in Table 1 below show that both the Fornell-Larcker and HTMT tests passed the minimum threshold of 0.60~0.90 to establish the discriminant validity of the model.

Table 1. Discriminant Validity.

	Fornell-Larcker					HTMT (0.60~0.90)				
	ACAP	**DT**	**EL**	**INTRA**	**PIP**	**ACAP**	**DT**	**EL**	**INTRA**	**CI do not include 1**
ACAP	0.783									Yes
DT	0.713	0.847				0.802				Yes
EL	0.522	0.677	0.832			0.572	0.78			Yes
INTRA	0.572	0.569	0.411	0.786		0.656	0.663	0.486		Yes
PIP	0.724	0.681	0.42	0.5	0.764	0.867	0.782	0.465	0.58	Yes

4.2. Structure Model

Before analyzing the structural model, the model was assessed for multi-collinearity issues; the inner VIF values were obtained by running the PLS algorithm with a "path weighted scheme". It was observed that all the inner VIF values were below the threshold value of five, which means that there was no collinearity issue in the model and researchers can continue with the structural model evaluation [61]. After checking the structural model for any collinearity issues, a four-step approach was adopted for the assessment of the structural model.

In the first step, R^2 was assessed for each latent variable, to establish the in-sample predictive power. The R^2 or coefficient of the determinant value expresses how much variance in a targeted variable is explained by the independent variables linked to it in a structural model. The threshold values for R^2 are 0.19 (weak), 0.33 (moderately strong), and 0.67 (substantially strong) [62]. All R^2 values in the present study except for INTRA (0.170) fell between moderately and substantially strong ranges. R^2 values in the range of 0 to 0.13 are not significant, 0.14 to 0.26 aretangent values and 0.27 and above are significant [63]. Both criteria show the very good in-sample predictive power of the structural model. The R^2 calculation revealed that entrepreneurial leadership, the intra-firm innovation network, the absorptive capacity, and the design thinking collectively explained a 64% variance in the product innovation performance. Similarly, entrepreneurial leadership explained 17%, 28.3%, and 45.8% of the variance in the intra-firm network, absorptive capacity, and design thinking, respectively. These R^2 values show the high in-sample predictive power of the model. In other words, EL together with INTRA, ACAP, and DT are good predictors of product innovation performance in a firm.

In addition to assessing and evaluating the R^2 value for all endogenous constructs in the structural model, it is also recommended to evaluate the change in R^2 when a specified exogenous construct is omitted from the structural model and to evaluate whether the omitted construct has a significant impact on the endogenous construct. This change in R^2 by omitting a specified exogenous construct is referred to as f^2 or effect size [64]. An f^2 value of 0.02 representsa small effect, a value of 0.15 representsa medium effect, and 0.35 represents the large effect of exogenous constructs [65]. The F square (f^2) values revealed that absorptive capacity (0.425) and design thinking (0.103) have a large effect size on product innovation performance whereas entrepreneurial leadership (0.022) has a small effect, and intra-firm network (0.002) has no effect. Similarly, entrepreneurial leadership has large effect sizes of 0.395, 0.844, and 0.204 on absorptive capacity, design thinking, and intra-firm network, respectively.

Furthermore, for a structural model assessment, Stone-Geisser's Q^2 Square was calculated through blindfolding. "In PLS-SEM, a Q^2 value of greater than zero for a specific endogenous reflective construct indicates path model's predictive relevance for a particular dependent construct and when the structural model shows predictive relevance, it accurately predicts data not used in model estimation". Q^2 is not a true measure of out of sample predictions but it combines aspects of in-sample explanatory power and out of sample predictions. According to previous studies, as a rule of thumb, Q^2 values of above zero, 0.25, and 0.5 show small, medium, and large predictive relevance, respectively [66]. In the present study, the Q^2 value of INTRA (0.094) showed small predictive power whereas

ACAP (0.159), DT (0.305), and PIP (0.325) showed medium predictive power. Table 2 below summarizes the results of R^2, f^2, and Q^2.

Table 2. Results of R^2, f^2 and Q^2.

Constructs	R^2	f^2				Q^2
		ACAP	DT	INTRA	PIP	
ACAP	0.283				0.425	0.159
DT	0.458				0.103	0.305
INTRA	0.170				0.002	0.094
PIP	0.640					0.325
EL		0.395	0.844	0.204	0.022	

A new technique for the true assessment of the out of sample predictive power of the model is PLS-Predict. As per the guidelines of Shmueli [67] the model under study showed a medium out of sample predictive power and relevance. As Table 3 shows below, PLS (RMSE) < LM (RMSE) for the majority of the items for the target construct, i.e., product innovation performance.

Table 3. Results of PLS-Predict.

Items	PLS-SEM(RMSE)	LM(RMSE)	PLS-SEM(RMSE)—LM(RMSE)
PIP-1	1.083	1.086	−0.003
PIP-2	1.147	1.154	−0.007
PIP-3	0.963	1.009	−0.046
PIP-4	1.081	1.059	0.022
PIP-5	0.859	0.867	−0.008
PIP-6	0.956	0.973	−0.017

After checking for the collinearity issue and model strength and quality, the path coefficients (hypothesized relationships), and their significance through bootstrapping were tested. The result of the direct relationships is presented in Table 4 below.

Table 4. Result of Direct Relationships.

Relationships	Path Coefficient	t Value	*p* Values	95% Confidence Interval	Sig $p < 0.05$	Hypothesis	Result
EL→PIP	−0.120	1.065	0.287	[−0.342; 0.105]	No	H1	Not Supported
EL→INTRA	0.412	4.263	0.001	[0.18; 0.573]	Yes	H2a	Supported
EL→DT	0.677	9.886	0.000	[0.510; 0.787]	Yes	H2b	Supported
EL→ACAP	0.532	5.754	0.000	[0.319; 0.690]	Yes	H2c	Supported

The present study followed the mediation approach, as this approach is considered as the most suitable approach for PLS-SEM [56]. The Sobel test [68] is traditionally used to test the significance of mediation relationships, however recent researchers have highlighted the statistical shortcomings of the Sobel test and recommend the use of bootstrapping to test the significance of relationships. Therefore, the bootstrapping technique was used in this study to check the significance. The result of the mediation analysis is presented in Table 5 below.

Table 5. Result of the Mediation Analysis.

	Indirect Effect	95% Confidence Interval	Sig $p < 0.05$	Direct Effect	95% Confidence Interval	Sig $p < 0.05$	Hypothesis	Result
EL→DT→PIP	0.221	[0.061–0.399]	Yes	−0.119	[−0.342; 0.105]	No	H3	Supported
EL→INTRA→PIP	0.014	[−0.098–0.116]	No	−0.119	[−0.342; 0.105]	No	H4	Not Supported
EL→ACAP→PIP	0.312	[0.175–0.462]	Yes	−0.119	[−0.342; 0.105]	No	H5	Supported

5. Discussion and Conclusions

The numerical data analysis reveals that entrepreneurial leadership has a relevant and significant direct relationship with intra-firm networks, design thinking, DT, and absorptive capacity. These results allow us to claim that we can accept the hypotheses (H2a, H2b, and H2c).On the other hand, we encountered an interesting finding: entrepreneurial leadership's direct relationship to product innovation performanceis insignificant (H1). The above-mentioned findings, i.e., entrepreneurial leadership's influence on the adoptive capacity, intra-firm networks, and design thinking, are in line with the previous literature and they emphasize that entrepreneurial leadership can enhance intra-firm collaboration, design thinking, and the absorptive capacity of the firm significantly [39,41,48,69]. However, the fact that the results revealed that entrepreneurial leadership does not directly influence the product innovation performance was a little surprising, because the literature highlighted the fact that EL is all about creating a conducive and suitable climate for the innovation to take place [35]. There is a strong connection between innovation performance and entrepreneurship; however, entrepreneurship is a context-dependent social process, which tries to bring together diverse resources to explore and exploit opportunities under the umbrella and direction of leadership. So, we suggest that further research should be conducted in different contexts to better understand the reason for this behavior [70]. Mediation analysis revealed that entrepreneurial leadership is working as a context-dependent phenomenon influencing product innovation performance through the tools of design thinking (H3) and absorptive capacity ACAP (H5), instead of having a direct influence. However, it does not have a significant influence on PIP through INTRA (H4), which means that INTRA is not mediating between EL and PIP. This result is surprising and against the findings of previous studies [47] and further research is needed to find out the reasons behind it.

5.1. Theoretical Implication

The present study has proposed and empirically tested a functional mechanism of entrepreneurial leadership comprising of design thinking, intra-firm networks, and absorptive capacity, through which entrepreneurial leadership affects a product innovation performance that requires minimum financial commitment and resources for execution, hence contributing to the theory of entrepreneurial leadership by proposing a new functional mechanism. Furthermore, the present study contributed to the theory of entrepreneurial leadership by synergizing it with the theory of design thinking by suggesting the use of design thinking tools and practices for the pro-active problem-solving characteristics of entrepreneurial leadership.

Moreover, most of the previous literature has studied product innovation performance from the perspective of the R&D budget and other financial perspectives requiring a huge financial commitment. Improving the innovation performance through these perspectives is difficult for firms in developing countries as they lack the required financial and managerial resources. This study, however, chosea different path and studied product innovation performance from the perspectives of entrepreneurial leadership, design thinking, and networking that do not require a huge financial commitment. Moreover, most of the previous studies have discussed the relationship between entrepreneurship, leadership, and product innovation performance separately. However, the literature regarding the combined impact of entrepreneurship and leadership (in the form of entrepreneurial leadership) on the product innovation performance is scarce, and the present study has made a significant contribution in this regard.

5.2. Managerial Implications

This study highlighted a very important point that entrepreneurial leadership has a very important role in innovation performance as established by many previous studies. However, as per the findings of this study, entrepreneurial leadership needs a mechanism to improve the product innovation performance of the firm. Therefore, managers must keep

this in mind; entrepreneurial leader characteristics alone arenot enough. A whole mechanism and set of tools such as design thinking, intra-firm networks, and absorptive capacity are required to improve the product innovation performance. Managers further need to understand that entrepreneurial leadership is very important for design thinking, intra-firm networks, and absorptive capacity. In other words, the presence of entrepreneurial leadership acts as a catalyst for design thinking, intra-firm networks, and absorptive capacity so that they can all work in conjunction for a better product innovation performance.

Management also has to understand that they have to create and promote an environment where employees are encouraged to act as entrepreneurial leaders; they must be encouraged to think out of the box and pro-actively. The main task of entrepreneurial leaders is to make their organization ambidextrous, which means that entrepreneurial leaders are always looking to explore and exploit opportunities and in the process, they tend to take risks and make mistakes. Furthermore, management has to encourage formal and in-formal intra-firm networking between employees for a better and quicker sharing of ideas and information and for quicker idea sharing and innovation.

5.3. Limitation and Future Research

The study has used a cross-sectional research design; however, all the variables used in this study are very dynamic and can change quickly over a short passage of time depending upon the circumstances. Therefore, to further validate the findings of this research, longitudinal research may be conducted, and its results may be compared with this study for better understanding. Moreover, the sample size is satisfactorily large; however, a further study is recommended with a larger sample size from a wider sample set of cities to further validate the results.

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Exploring the Relationship between Communication and Success of Construction Projects: The Mediating Role of Conflict

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Abstract: The success of a construction project is a widely discussed topic, even today, and there exists a difference of opinion. The impact of communication and conflict on project success is an important, but least addressed, issue in literature, especially in the case of underdeveloped countries. Miscommunication and conflict not only hinder the success of a project but also may lead to conflicts. The focus of this paper was to examine the impact of communication on project success with the mediating role of conflict. By using SPSS, demographics, descriptive statistics and correlation were determined. Smart PLS version 3.0 was used for confirmatory factor analysis (CFA), internal accuracy and validity estimates, hypothesis checking and mediation testing. The results showed that formal communication has a negative impact on the success of a construction project, resulting in conflicts among project team members, whereas informal communication and communication willingness have a positive impact on project success because people tend to know each other, and trust is developed. Task, process and relationship conflicts were used as mediating variables. It was found that task conflict effects the relations positively because project team members suggest different ways to do a certain task, and, hence, project success is achieved. On the contrary, process conflict and relationship conflict have a negative impact on communication and project success. Both of these conflicts lead to miscommunication, and project success is compromised. Hence, it is the responsibility of the project manager to enhance communication among project team members and to reduce the detrimental effects of process and relationship conflict on project success.

Keywords: communication; formal communication; informal communication; communication willingness; conflict; project manager

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1. Introduction

The construction industry plays a vital role in the development of the country. It has the potential to boost the economy of the country and creates employment opportunities as well [1]. It uses laborers and skilled professionals to deliver a project within the specified time and within the budget allocated to satisfy the client or customer [2].

The construction industry is purely a project-based industry and a project is temporary in nature [3]. A construction firm can get the competitive edge based on in its

performance in the market [4]. The three major participants are Client (Owner), Contractor and the Consultant, and the relationship among them is temporary and fragile [5]. A construction project, therefore, involves teams of the Client, Contractor and the Consultants. Construction project teams communicate to exchange information from each other [6]. The information could be financial or technical. Changes to drawings, specifications, and design and progress status are the key elements to communicate among project teams [7]. Effective communication is needed to deliver a project on time. On the other hand, miscommunication leads to failure in achieving objectives of a project [8]. The project teams work with each other and they depend on each other, which may lead to conflicts [9]. Conflicts in projects make it difficult to achieve project objectives and may lead to failure [10]. Conflicts arise in projects over resources, duties, tasks, work hours, incentives, etc. It is the responsibility of project manager to resolve the conflict without any time delays to prevent the project failure. Success of a construction project is a widely discussed topic, even today, and there exists a difference of opinion in this regard. Since, the inception of project management, the success of the project is measured by the iron triangle, i.e., cost, time, scope and quality [11]. A construction project is successful if it is constructed and operated successfully [12]. A project, if successful, causes satisfaction of the client [13].

In the literature, proper communication and co-ordination have been identified as a key factor in success of a project. In [14,15], it was found that conflict has an inverse relation with project success. It is also evident from the literature that project success and sustainability seem to fluctuate in the same manner, and there are no significant discrepancies between them [16,17]. The relationship between different levels of integration of sustainability and project success is not a simple one. The literature identified nine dimensions of sustainability and six measures of project success [18]. Another study by [19] found cases where successful projects were induced by sustainability and also where a sustainable practice did not lead to success. They concluded that there should be other factors influencing a project's outcome. According to [20], project success is linked to the project manager's ethics in business. In fact, the International Project Management Association code explicitly mentions sustainability as one of the professional responsibilities of the project manager, without explicitly linking this to project success.

The existing literature is extensive with regard to communication types, conflict types and project success, but is limited in studying the relationship between them, especially in the case of the construction industry. Secondly, the norms, culture, diversity and operating procedures affect the governing rules and regulations of the construction industry of any country, so the impact could be case specific. Hence, it is important to investigate them and formulate a better policy for practitioners in the construction industry. The above section presented a brief introduction of the problem; in Section 2, an in-depth review of previous and relevant research works on team communication, team conflict and project success, along with some contradictions and gaps in previous research are discussed. Section 3 presents a research framework of the study. In Section 4, empirical findings are discussed. The discussion on results is presented in Section 5. The conclusion and the managerial implications, along with limitations and future recommendations, are discussed in Section 6.

2. Literature Review

2.1. Team Communication

The transfer of information from one person to another is referred to as communication [21]. Ref. [22] has argued that an interactive platform for stakeholders may be required to overcome communication difficulties. According to [23], effective communication is very important and fundamental in project management since teams work together to achieve project goals. Construction teams need to have good communication strategies because of the temporary and fragmented nature of the construction industry [24]. Ref. [6] has divided communication into formal and informal communication. Both of these are necessary to make a project successful. According to [25], willingness to communicate with

the team is another dimension of communication that needs to be studied. This study has taken three dimensions of communication, i.e., formal and informal communication and communication willingness.

2.2. Team Conflict

A disease that arises because of differences in goals and interest is conflict [26]. According to [27], conflict arises because of differences in opinion, ideas, beliefs and interest of people involved in a project. A conflict can have a positive impact on an organization's business, e.g., increasing productivity and exploring better solutions, but at the same time, a conflict can have a negative impact as well, such as poor communication and employees not willing to co-operate with each other [28]. Present-day projects need multiple organizations to work together to accomplish project tasks, therefore, making the teams more prone to develop conflict among them [29]. In the projects of the modern era, the possibility of conflicts in projects is increased because of the diversified background of individuals within teams [30]. According to [31], conflict is of two types, namely, task oriented and relationship oriented. However, there is another type of conflict referred to as process conflict [32]. In this paper, conflict among people involved in the project was divided into three types as task, process and relationship conflict.

2.3. Project Success

Project success has become vitally important in the field of project management. It has been discussed widely since the inception of this field. Project success has attracted many authors [33,34]. Many authors have come up with different factors that are critical to ensuring a project as successful [35]. Ref. [36] examined the critical success factors (CSFs) for construction and PPP projects, respectively, have been identified. To understand project success, some authors have emphasized the consideration of perspectives. In the short term, project success could be measure by the iron triangle, but in the long term, customer satisfaction and successful operations of building or facility also come under the definition of project success [13,37].

2.4. Impact of Team Communication on Project Success

Team communication is discussed broadly in the literature as it plays an important role in the success and goal accomplishment of a project [38]. With the evolution of time, project success has become more difficult, and the impact of communication on project success demands attention [39]. According to [38], team communication management is of great importance in the field of project management. The authors of [40,41] have also put great emphasis on communication among individuals and teams, since it significantly affects the project.

There are three dimensions used in the literature to measure communication, i.e., formal communication, informal communication and willingness to communicate [42–44]. Formal communication includes meetings, document sharing, etc., and barriers among team members are not removed by this form of communication [44,45]. On the other hand, by the help of informal communication, people tend to know each other's culture, habits, and skills, therefore, conflicts are resolved, and project success is achieved [46]. According to [47,48], willingness to communicate increases information sharing among teams and, hence, facilitates project success. This study hypothesized that:

Hypothesis 1 (H1). *There exists a relationship between formal communication and project success.*

Hypothesis 2 (H2). *There exists a relationship between informal communication and project success.*

Hypothesis 3 (H3). *There exists a relationship between communication willingness and project success.*

2.5. Communication Conflict Interaction and Its Impact on Project Success

The construction industry plays a vital role in the economy of any country and is a project-based industry [49]. Due to large-scale projects, multiple teams and reduced profits, conflicts continue to arise [50]. According to [51], conflicts must be avoided to the maximum extent because of their devastating nature. Conflict is a serious difference of opinions among individuals or teams and can lead to cost overruns, time delays and damage to an organization's business and, hence, may lead to underperformance of a construction project [52]. According to [5], lack of communication is one of the reasons that can contribute to conflicts arising. Communication problems do occur on site, and these must be solved timely and on the spot (if possible) to prevent poor relation conflicts among individuals [51]. For project success, many critical success factors have been identified by authors since the inception of this field. [53], argued that conflict leads to failure of a project and management of conflict is important in determining the fate of a project. Communication difficulties are devastating for the project goals and can lead to conflict, which ultimately leads to failure of the project [54].

From the literature, it is evident that both communication and conflict do affect the project success.

According to [55], task conflict has a positive impact on project success. The study tests the following hypotheses:

Hypothesis H4 (H4a). *The relationship between formal communication and project success is mediated by task conflict.*

Hypothesis H4 (H4b). *The relationship between informal communication and project success is mediated by task conflict.*

Hypothesis H4 (H4c). *The relationship between communication willingness and project success is mediated by task conflict.*

When members of a project team have disagreements among each other regarding the procedure or processes involved in the project, process conflict arises [56]. According to [55], process conflict is positively influenced by informal communication and communication willingness but is negatively related to formal communication. Process conflict has a negative impact on project success [55]. The study empirically tests the following hypotheses:

Hypothesis H5 (H5a). *The relationship between formal communication and project success is mediated by process conflict.*

Hypothesis H5 (H5b). *The relationship between informal communication and project success is mediated by process conflict.*

Hypothesis H5 (H5c). *The relationship between communication willingness and project success is mediated by process conflict.*

The negative emotions or feelings of one team member for another can lead to relationship conflict among them [57]. According to [58], relationship conflict has a negative impact on project success. According to [59], relationship conflict is positively related to formal communication but negatively related to informal communication and communication willingness. This study hypothesized that;

Hypothesis H6 (H6a). *The relationship between formal communication and project success is mediated by relationship conflict.*

Hypothesis H6 (H6b). *The relationship between informal communication and project success is mediated by relationship conflict.*

Hypothesis H6 (H6c). *The relationship between communication willingness and project success is mediated by relationship conflict.*

3. Research Methodology

3.1. Research Framework

The success of a construction project is dependent on many factors and is discussed widely. While executing a project, different people work together in teams and communicate with each other leading the project to its pre-determined objectives. However, miscommunication leads to conflicts, which, if not resolved timely and properly, can lead a project to a partial or complete failure.

Hence, there is a need to study the relationship of communication types with project success and also to study the mediating effect of different types of conflicts on this relationship [59].

Our theoretical model is based on the research work of Wu et al. [59]. The items to measure the dimensions of communication were taken from the research work of [43,45], whereas the items to measure types of conflict were taken from the research work of [59]. Project success was measured with the help of items used by [60]. The research framework is shown in Figure 1.

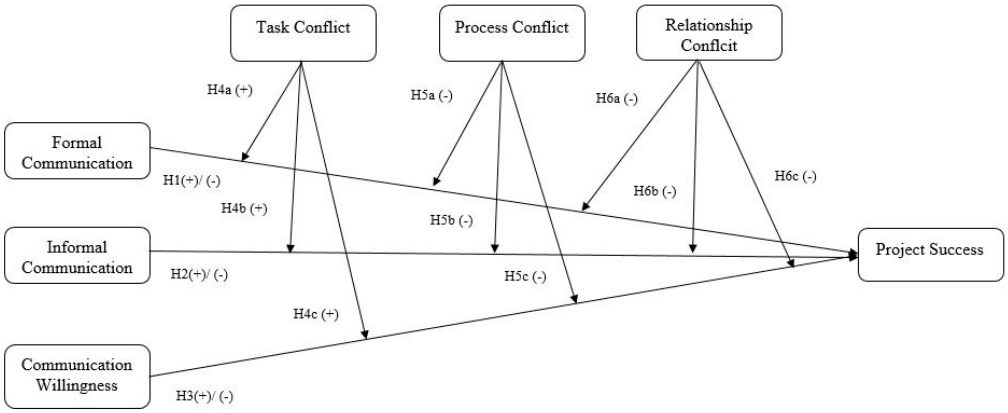

Figure 1. Research framework showing direct relation of communication types with project success and mediating role of conflict types.

3.2. Population and Sampling

The target population was large- and medium-sized construction firms based in Lahore, and our respondents were professionals (top and middle management) working in these firms. The reason for choosing Lahore city was that Lahore is the second largest metropolitan city of Pakistan. It is also the capital city of Punjab province [61]. Lahore city is the main hub for construction firms. Most of the projects are initiated from this city and are then executed in different cities. The professionals perform their duties at the construction site(s) and also pay visits to their offices for meetings and other official engagements. A list of construction companies was acquired from the website of the Pakistan Engineering Council (PEC), which is a body established under the Constitution of Pakistan to regulate the engineering profession in Pakistan. At least two professionals from a firm were approached to avoid single source bias.

Cochran's formula was used to evaluate the sample size. It is used when target population size is unknown or infinite [62]. A total of 385 questionnaires were distributed, and 267 valid responses were received from twenty-seven companies. When dealing with average sample sizes, the technique of Structural Equation Modeling (SEM) was used.

According to [63], this technique gives the best results when the sample size is small. For testing of the hypotheses and mediation analysis, Smart PLS software was used. Smart PLS is accepted as the most comprehensive software by the research community, especially when SEM technique is employed [64].

4. Results

4.1. Demographic Analysis

For the computation of demographics and reliability, Statistical Package for Social Sciences (SPSS) version 21 was used. The demographic calculations are shown below in Table 1.

Table 1. The demographic analysis of respondents.

Respondent Designation	Frequency	Percent
Planning Engineer	68	25.5
Project Engineer	64	24.0
Project Manager	45	16.9
Senior Engineer	71	26.6
Chief Executive	6	2.2
Managing Director	13	4.9
Experience in Years		
<5 Years	29	10.9
5–10 Years	55	20.6
10–15 Years	123	46.1
15–20 Years	26	9.7
>20 Years	34	12.7
Cost of Last Completed Project		
<PKR 50 M	47	17.6
PKR 50–100 M	82	30.7
PKR 100–250 M	47	17.6
PKR 250–450 M	60	22.5
>PKR 450 M	31	11.6
Total	267	100

Planning engineers who gave responses were 68 in number, constituting a percentage of 25.5%; project engineers were 64, with a percentage of 24%; project managers were 45, with a percentage of 16.9%; senior managers were 71, with a percentage of 26.6%. Similarly, chief executives and managing directors were 6 and 13 in number, with percentages of 2.2% and 4.9%, respectively. Experience is a critical factor when someone is asked to give a response, as experience is linked to more exposure to the problems being faced. The respondents with experience less than five years were 29, from five to ten years were 55, from ten to fifteen years were 123, from fifteen to twenty years were 26, and above twenty years were 34 in number.

Respondents were asked to write the cost of their last completed projects. The respondents from large organizations completed their last project with a much higher cost. The projects with cost less than fifty million were 47, from fifty to one hundred million were 82, from one hundred to two hundred and fifty million were 47, from two hundred and fifty to four hundred and fifty were 60, and above four hundred and fifty were 31 in number.

4.2. Reliability

To calculate internal consistency, the Cronbach alpha was used. A value greater than 0.7 indicates good constructs [65]. The values are shown in Table 2 below.

Table 2. Reliability of variables.

Variable Description	Coded Name	Number of Items	Cronbach's Alpha Value
Formal Communication	FC	7	0.92
Informal Communication	IC	6	0.799
Communication Willingness	CW	6	0.75
Task Conflict	TC	7	0.775
Process Conflict	PC	6	0.814
Relationship Conflict	RC	7	0.883
Project Success	PS	11	0.916

4.3. Confirmatory Factor Analysis (CFA)

CFA is a theory-driven approach to empirically test the established theory with the help of a questionnaire. SmartPLS (version 3.0) software was used for CFA.

Table 3 below shows the loading (direct) scores. The loading scores of indicators that represent a construct must be greater than the values in other rows under different constructs.

Table 3. Direct loading scores.

	CW	FC	IC	PC	PS	RC	TC
CW1	0.844						
CW2	0.843						
CW4	0.548						
CW5	0.782						
FC1		0.834					
FC2		0.821					
FC3		0.814					
FC4		0.798					
FC5		0.854					
FC6		0.819					
FC7		0.808					
IC1			0.74				
IC2			0.764				
IC3			0.823				
IC4			0.831				
IC5			0.786				
IC6			0.913				

Table 3. *Cont.*

	CW	FC	IC	PC	PS	RC	TC
PC2				0.877			
PC5				0.913			
PC6				0.762			
PSS1					0.87		
PSS2					0.895		
PSS3					0.844		
PSS4					0.842		
PSS5					0.821		
PSS9					0.764		
RC1						0.823	
RC2						0.818	
RC3						0.801	
RC4						0.847	
RC5						0.821	
RC6						0.508	
RC7						0.74	
TC1							0.643
TC2							0.719
TC3							0.838
TC4							0.73
TC5							0.692

Secondly, an indicator is retained if its direct loading score is greater than 0.7 [66]. According to [67], there is maximum allowance of 30% reduction in indicators. The number of items in the questionnaire was previously 50, but 12 were discarded, whereas the maximum allowed was 15 in our case. The discarded items were CW3, CW6, PC1, PC3, PC4, PSS6, PSS7, PSS8, PSS10, PSS11, TC6 and TC7.

The loading scores are also presented in Figure 2.

4.4. Discriminant Validity

The following Table 4 represents the results of the Fornell and Larcker criterion. The values in diagonal are bolded and they represent the values of the square root of average variance extracted (AVE). If the bold values are greater than the other in the same column, then the discriminant validity is established.

4.5. Testing of Hypotheses

For the testing of the hypotheses, Smart PLS (version 3.0) was used.

4.5.1. Direct Relations

Communication was divided into three dimensions, namely, as formal communication, informal communication and communication willingness. The first three hypotheses were concerned about the impact of communication on project success. The findings are stated in Table 5.

Table 4. Discriminant validity by Fornell and Larcker criterion.

	CW	FC	IC	PC	PS	RC	TC
CW	**0.764**						
FC	0.102	**0.821**					
IC	0.717	0.072	**0.728**				
PC	0.454	0.051	0.461	**0.853**			
PS	0.106	0.667	0.069	0.045	**0.84**		
RC	0.116	0.696	0.082	0.095	0.692	**0.773**	
TC	0.785	0.091	0.665	0.526	0.066	0.057	**0.727**

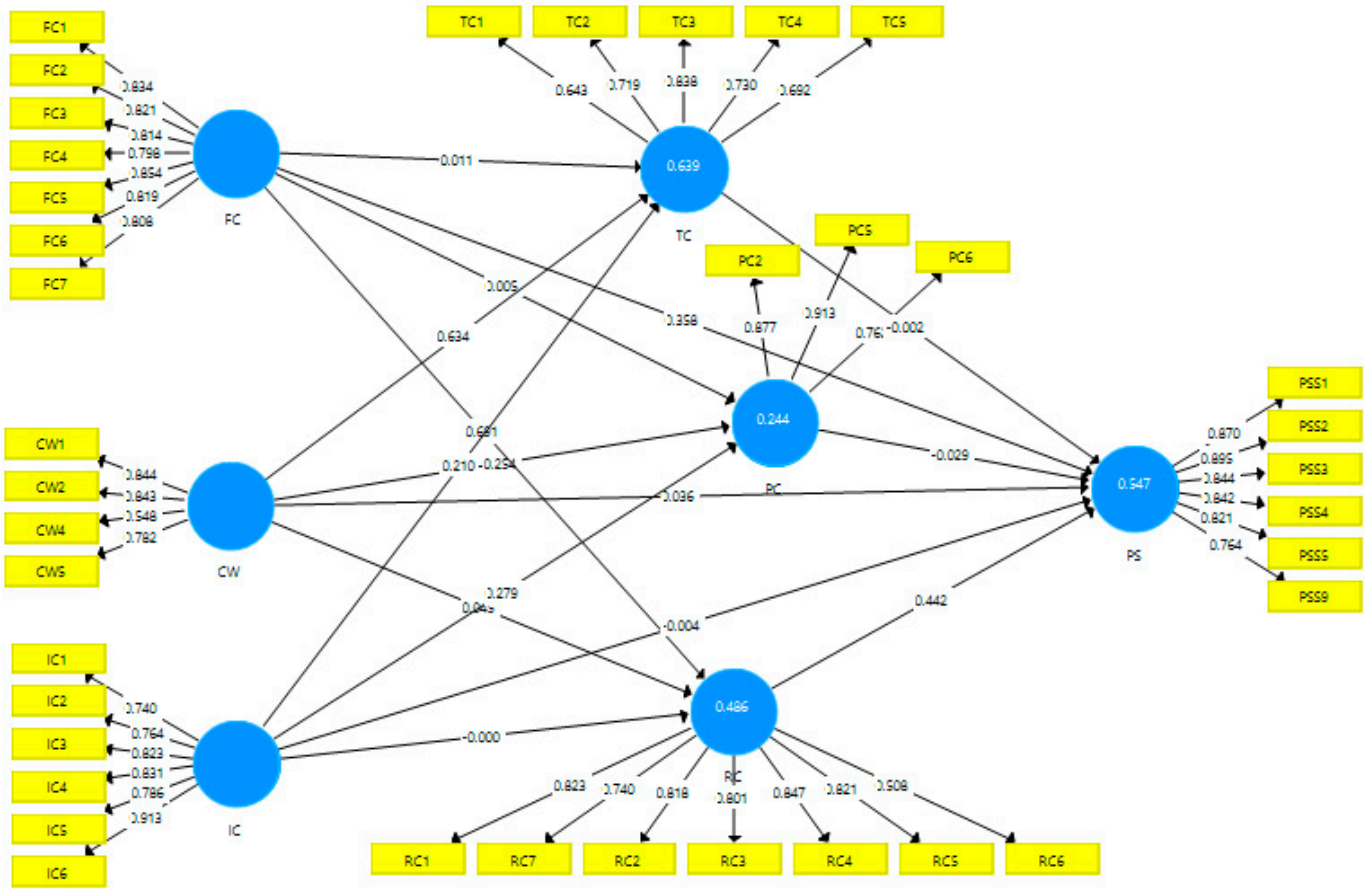

Figure 2. Confirmatory factor analysis.

Table 5. Results of Hypothesis 1 (H1), Hypothesis 2 (H2) and Hypothesis 3 (H3).

Hypotheses	Hypothesis Direction	Original Sample (O)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	Results	Impact
H1	FC -> PS	−0.358	0.078	4.597	Supported	−ve
H2	IC -> PS	0.361	0.062	5.822	Supported	+ve
H3	CW -> PS	0.158	0.08	1.975	Supported	+ve

In Table 5, H1 states that here exists a relationship between formal communication and project success. The direction of the hypothesis was not mentioned in the hypothesis due to mixed evidence available in the literature. The results indicated a negative relationship and the hypothesis was accepted. H2 states that there exists a relationship between informal communication and project success. The hypothesis was validated, as the *t* value is highly significant. H3 states that communication willingness impacts the project success, which was also validated, as the *t* value in this case was 1.975, which is greater than 1.65. The hypothesis was accepted with positive impact.

4.5.2. Indirect Relations

Three mediators (task conflict, process conflict and relationship conflict) were used to check the indirect relationship. The results are presented below:

Task Conflict as a Mediator

The results of task conflict as a mediator are presented in Table 6 below.

Table 6. Task conflict as a mediator.

	Original Sample (O)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)
Formal Communication			
FC -> TC	−0.118	0.04	2.95
TC -> PS	0.314	0.077	4.077
FC -> PS with TC as mediator	0.321	0.07	4.58
Informal Communication			
IC -> TC	0.21	0.06	3.517
TC -> PS	0.314	0.077	4.077
IC -> PS with TC as mediator	0.141	0.019	7.42
Communication Willingness			
CW -> TC	0.634	0.056	11.301
TC -> PS	0.314	0.077	4.077
CW -> PS with TC as mediator	0.167	0.056	2.982

In Table 6, when the mediator was introduced in formal communication, $t = 4.58$, the strength of the relationship increased with the mediator. The mediator played a significant role in the informal communication and communication willingness.

Process Conflict as a Mediator

The empirical findings of process conflict as a mediator are presented in Table 7 below.

The relationship of formal communication with process conflict and process conflict with project success was significant. However, the *t* value was significant when the process conflict was introduced as a mediator. The hypothesis was accepted with negative impact of process conflict as a mediator.

Relationship Conflict as a Mediator

This paper hypothesized that the relationship between formal communication and project success is mediated by relationship conflict. Results are presented in the Table 8.

Table 7. Process conflict as a mediator.

	Original Sample (O)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)
Formal Communication			
FC -> PC	0.0187	0.056	3.339
PC -> PS	−0.293	0.058	5.051
FC -> PS with PC as mediator	−0.419	0.093	4.505
Informal Communication			
IC -> PC	0.279	0.082	3.396
PC -> PS	−0.293	0.058	5.051
IC -> PS with PC as mediator	−0.127	0.054	2.351
Communication Willingness			
CW -> PC	0.254	0.09	2.807
PC -> PS	−0.293	0.058	5.051
CW -> PS with PC as mediator	−0.289	0.071	4.07

Table 8. Relationship conflict as a mediator.

	Original Sample (O)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)
Formal Communication			
FC -> RC	0.691	0.041	17.068
RC -> PS	−0.442	0.072	6.109
FC -> PS with RC as mediator	−0.302	0.05	6.074
Informal Communication			
IC -> RC	0.616	0.074	8.324
RC -> PS	−0.442	0.072	6.109
IC -> PS with RC as mediator	−0.244	0.032	7.62
Communication Willingness			
CW -> RC	0.245	0.069	3.55
RC -> PS	−0.442	0.072	6.109
CW -> PS with RC as mediator	−0.05	0.027	1.85

The addition of relationship communication as a mediator between formal communication and project success was statistically significant, hence, the hypothesis was accepted. However, the impact was negative.

When relationship conflict was introduced as a mediating variable in communication willingness and project success, the *t* value was relatively lesser, i.e., 1.85, but greater than 1.65, hence, the hypothesis was accepted with positive impact.

5. Discussion

Construction projects are increasing day by day. Their complexity is also increasing, hence, demanding more expertise and more involvement of people. The developing countries are faced with the problems of lack of facilities such as educational institutes, hospitals, high rise buildings, etc., so construction work is always in continuation. Communication among people is very important and plays an important role in project completion and success. People with different backgrounds, culture, norms and behaviors, interact with each other and, hence, conflict arises. This research was focused on answering the two

questions: first, to check and analyze the impact of communication on project success; second, to check the mediating role of conflict on the relationship between communication and project success.

Communication in this paper was divided into three dimensions, i.e., formal communication, informal communication and communication willingness. People involved in projects communicate in different ways. When they communicate through meetings, in office discussions, emails, etc., they communicate formally. When people communicate with each other exchanging information about each other's background, habits, family, etc., this is referred to as informal communication. According to [43], communication willingness is basically the will to talk to each other that helps in the sharing of critical data among them and is an important factor that leads to enhanced coordination and trust. The first three hypotheses were concerned about the relationship between communication and project success. The relationship of formal communication with project success was found statistically significant, but the impact was negative (H1). It was because of the reason that, although formal communication enhances coordination among teams or people, it does not help them in developing trust mechanisms and, as a result, the desired project success is not achieved, and differences between them are not resolved by this form of communication [44,45].

Informal communication was also found to be statistically significant and positively affecting project success (H2). When people communicate informally, they tend to know more about each other, including about the other's culture, background, skills, etc., and so conflicts and differences are more likely to be resolved, and project success is achieved, which is also supported by some previous research [46].

The relationship of communication willingness and project success was also statistically significant and positive (H3). The will to communicate eases the way of information sharing between people, differences are more readily resolved and, as a result, project success is facilitated [48,59].

When task conflict was introduced as a mediator between the formal communication and project success, the results were significant. A positive impact was observed, but the mediation was observed to be partial (H4a). The reason is, in task-oriented conflict, people in teams argue and agree or disagree with each other in the ways to accomplish a certain task, which results in an increase in productivity, and project success is achieved. The effect of formal communication is negative on project success, but this effect is lessened by task conflict [68].

Similarly, when task conflict was used as a mediator between informal communication and project success, the impact was observed to be positive, and mediation was partial (H4b). In informal communication, people tend to know each other, and communication is enhanced. A role is played by task conflict in this regard. With the help of informal communication, people develop trust. So, they argue with each other about the execution or possibilities of execution of a certain tsk and, thus, find different ways to accomplish a certain task, and project success is facilitated [59].

Communication willingness and project success were mediated by task conflict positively and significantly. Mediation was partial in this case (H4c). When they have a will or intention to talk to each other and know each other, then hesitation is reduced and frankness increases, accomplishing a task becomes easier for them, and the project becomes successful [68,69].

When process conflict was introduced as a mediator between formal communication and project success, the negative impact of formal communication was enhanced because of the negative impact of process conflict on the relation. Mediation was observed to be partial (H5a). A difference in opinion about the responsibility of certain tasks or authoritarian issues or assignment of duties is referred to as a process conflict. As discussed previously, formal communication does not remove barriers among team members but, at the same time, if process conflict arises then results are detrimental for project success [70].

When process conflict is introduced as a mediator between informal communication and project success, the impact is negative with partial mediation (H5b). When process conflict is introduced as a mediator between communication willingness and project success, the impact is negative with partial mediation (H5c). The reason behind this type of conflict damages trust and collaboration among team members and they hesitate or do not bother to talk to each other, and project success suffers [31,70].

It is found that relationship conflict has a negative impact on all the direct relations, and mediation is observed to be partial. When relationship conflict was introduced as a mediator between formal communication and project success, the negative impact of formal communication increased due to the relationship conflict as it was also inducing a negative impact (H6a). When people have private or personal quarrels and differences, then they begin to disagree with each other in formal means of communication, and project success is halted [68].

When informal communication and project success were mediated by relationship conflict, the impact was found to be negative on this positive relation (H6b). This conflict is related to relations among people and, if emotions are hurt, then even informal communication causes conflicts among them. Similarly, the mediating effect of relationship conflict was observed to be negative on the relation of communication willingness and project success (H6c). It is because of the reason that disagreements due to personal differences make them hesitate to communicate freely, and information is not transferred timely, hence, project success is halted [70].

6. Conclusions and Managerial Implications

In developing countries, construction projects are increasing day by day. However, the construction industry is faced with the problems of miscommunication and conflict. Achieving project success is becoming increasingly difficult with every passing day. The main purpose of this study was to analyze the effect of communication types or dimensions on project success. It has been found that formal communication negatively affects the project success, whereas informal communication and communication willingness have a positive impact. The results of the direct relations of this study revealed and suggested that the project managers and owners of the companies must encourage healthy communication among team members. A communication mechanism must be developed at sites or site offices and must be followed by all teams under the supervision or leadership of the project manager. Official meetings, discussions, and emails are a form of communication, but since these mediums do not enable people to get to know each other, coordination in a task is difficult to achieve. The view of some researchers is that informal communication has a devastating nature on project success, but the empirical results suggested that informal communication enhances trust and coordination, which is also suggested by some researchers. Willingness to communicate must also be encouraged because people tend to know each other, and this is important for the development of trust and coordination, which is important to achieve project success.

When people or team members challenge someone's authority or refuse to do a task directed by a superior, then not only does the project success suffer, but conflict also arises and member(s) start to quarrel with each other, and the project progress is affected badly and, in some circumstances, the project temporarily stops its progress. Similarly, when team members have differences among themselves over personal issues or personal liking or disliking, then project success is not achieved. It can be concluded that task conflict must be encouraged by the project manager, whereas process and relationship conflict must be avoided to the maximum extent, and a strong conflict resolution mechanism is needed to make projects successful.

These findings can help policymakers, constructors, and marketers to provide proper training and services to improve communication skills of employees to reduce conflicts and achieve project success. This study can also help investors to assess the results of their newly launched projects and provides information on how training can bring change to

the attitudes of employees. Furthermore, it explores the main factors involved in raising conflict through different types of communication.

Limitations and Future Recommendations

There are several limitations of this study. First, only professionals from Lahore city were approached. The responses of project managers were relatively lower than the other designated professionals. Respondents from consultants and clients were lesser in number. The model can be tested in other settings and can make a comparison between emerging and developed economies. The introduction of task, process and relationship conflict, as a mediating variable, resulted in partial mediation, indicating the need to introduce some other variables as a mediator in the model, such as contract types and trust among team members, etc.

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Linking Entrepreneurial Orientation with Innovation Performance in SMEs; the Role of Organizational Commitment and Transformational Leadership Using Smart PLS-SEM

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Abstract: Entrepreneurial orientation has become an enormously significant construct in the innovation studies literature. Predominantly for SMEs, its role has been widely recognized in almost all regional contexts across the globe. The present study is aimed at investigating the effects of entrepreneurial orientation, transformational leadership and organizational commitment on innovation performance. The data for the present study were collected from 1095 employees working at various levels in SMEs. The present study used partial least square structural equation modeling to examine the constructed hypotheses. The findings suggested the significantly positive direct relationships among entrepreneurial orientations, organizational commitment and innovation performance. Besides, organizational commitment positively mediated the relationships between entrepreneurial orientation and innovation performance. Additionally, this study also found the significant moderation of transformational leadership among entrepreneurship orientation and organizational commitment. Leaders of small and medium-sized enterprises should practice entrepreneurial orientation (innovativeness, proactiveness, and risk-taking) and transformation leadership (articulating a compelling vision, focus on goal achievement, and creative problem solving) to enhance the innovation performance of their firms. Moreover, this study provides a robust mechanism for leaders at SMEs to develop strategies for enhancing the willingness of the firms to bring innovation and offer new products and services. The policymakers should enhance the emotional attachment of employees with their firms, sense of moral obligation to remain with the firm which will, in turn, increase the organizational commitment of employees for innovation performance. The study provides empirical evidence to the resource-based view in the context of SMEs. The study delivers solid theoretical and practical implications to experts, leaders and policymakers.

Keywords: entrepreneurial orientation; innovation performance; organizational commitment; transformational leadership; small and medium-sized enterprises

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1. Introduction

Small and medium-sized enterprises (SMEs) of any developing country are a key instrument in providing job opportunities and escalating economic growth. Likewise, in Pakistan, SMEs contribute more than 99% of the business, consisting of a major share in manufacturing exports (25%). The major portion of the country's gross domestic product

(GDP) (Approximately 40%) maintained through SMEs—and they share the 30% net exports—optimizes the value addition by 28% and provides a huge amount of employment opportunities [1,2]. SMEs create job opportunities, support innovation, minimize income differences and support industrializations. Hitherto, SMEs are considered as one of the major poverty reduction sources as they create employment opportunities for the highly sensitive cluster (i.e., low income) of the country [3].

Recently, entrepreneurship has emerged as a critical contributor to economies, where entrepreneurial orientation is fundamental for success. Entrepreneurial orientation refers to the actions, procedures, policies, methods, decision-making strategies and practices within an organization, and supports entrepreneurial decisions in SMEs [4]. The literature has fairly maintained that entrepreneurial orientation is significantly associated with innovation performance [5,6], and organizational commitment [7] of firms. The firm's innovation level depicts the entrepreneurial orientation of the firm [8]. Many studies have elaborated the instrumental components of entrepreneurial orientation. For instance, Omerzel [9] mentioned risk-taking, proactivity, aggressive competition, customer orientation and autonomy. Whereas, Jambulingam, Kathuria [10] maintained six critical dimensions: reactiveness, innovativeness, aggressive competition, risk-taking, autonomy, and motivation as essential entrepreneurial orientation factors. Bringing it together, these emerging studies [11–17], mainly recommended the use of three most cited dimensions of entrepreneurial orientation, namely innovativeness, means the willingness to support innovation, risk-taking for innovation [10] and proactiveness, in seeking new opportunities to tackle market challenges and responding with innovative solutions [18]. This present study is based on the foundational theory, which is the "resource-based view (RBV)" developed by Barney [19]. RBV focuses on the resources as internal components of the organization and enhances the firm performance and competitiveness [20]. The previous literature is indicative that RBV is closely related to entrepreneurial orientation and its innovation abilities by identifying novel ideas, risk-taking, and proactive skills that enhance the SMEs' performance [8].

Sriviboon [21] suggested that technology adoption and innovation performance are critical for organizations' success, which can be significantly predicted through entrepreneurial orientation [22,23]. According to Wu and Gong [24], innovation performance consists of the firm's indulgence in technology, development of economic and innovation goals and attaining them through technology evolution, proficient business policies and advanced research and development capabilities. Studies in the past have critically examined the process and product innovation (levels of innovation) and further suggested a comprehensive measurement scale, including five critical factors of innovation performance, such as the quantity of manufactured goods, technological methods, development feat ratio, industry response and usage of advanced technology in production processes [25,26]. Hence, SMEs must adopt entrepreneurial orientation characteristics to enhance their innovation performance [22,27,28] and OC [7,29]. The present study concentrates on three characteristics of entrepreneurial orientation, "innovativeness, risk-taking and proactiveness" [8].

Leaders play a vital role in adopting entrepreneurial orientation's characteristics and positively influencing innovation performance and organizational commitment of SMEs. Literature has established that characteristics of transformational leadership, "including idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration", significantly influence the innovation performance of SMEs [30]. Few past studies also examined transformational leadership's positive impacts on organizational commitment [31,32]. Tian, Shuja [33] discussed that transformational leadership emphasizes practical issues, sets benchmarks, establishes understandings, shapes, and encourages attaining employees' goal attaining behavior. Therefore, the present study projects the moderating role of transformational leadership among entrepreneurial orientation and organizational commitment. According to Lambert, Kelley [34], organizational commitment refers to a positive relationship between the employees and firms, and affective commitment refers to a psychological connection with the firm [35,36]. Following the direct and indirect relationships among entrepreneurial orientation, innovation performance and

organizational commitment, the mediation mechanism of organizational commitment between entrepreneurial orientation and innovation performance relationships is essential to explore. For instance, Freixanet, Braojos [37] studied open innovation as mediation between international entrepreneurial orientation and innovation performance. Akbar, Bon [38] found the mediating role of innovation (radical and incremental) between entrepreneurial orientation and innovation performance. However, there is an observable gap between the intervening role of organizational commitment among entrepreneurial orientation and innovation performance within the context of SMEs in developing economies.

Entrepreneurial orientation is critical for SMEs, because all SMEs are striving to survive in the industry and face fierce competition from the big players. To compete with the big firms and gain a competitive position in the industry, SMEs have to take risks to invest in innovative products and services, enter into new potential markets and take rigorous innovative interchanges. Additionally, SMEs need to innovate and be proactive in designating their strategic goals and practices to compete in the industry. Such objectives could only be achieved through the entrepreneurial orientation [8,39,40]. Entrepreneurial orientation has the potential to heighten the level of organizational commitment to a large extent. Organizational commitment is essential to develop inner drive in employees to participate in innovation activities [41,42] and improve SMEs performance [43,44]. In addition, it is also vital to notice the role of the leadership support in enhancing the commitment level of employees. The literature advocates that transformational leadership is best suited to bring pivotal changes in employee behaviors and firm strategies to achieve a firm's innovation performance goals [45,46]. Therefore, this study investigates the direct effects of entrepreneurial orientation on innovation performance and indirect effects of organizational commitment (mediating) and transformational leadership (moderating) on the relationships between entrepreneurial orientation and innovation performance.

The current study is a significant addition in the development of an inclusive mediating mechanism of organizational commitment on innovation performance using Resource-Based View as foundation theory. Few previous studies are relative to the context in terms of the moderating role of organizational commitment on innovation [47], leaving intentions [48], employee innovation and participative leadership [49], leaders' behavior, performance and job satisfaction [50]. However, the present study advances the mediation model of organizational commitment among the relationship of entrepreneurial orientation and innovation performance in the context of the developing economy. Moreover, few past studies have examined transformational leadership's moderation role on the correlation among entrepreneurial orientation and firm performance and entrepreneurial orientation and firm performance and effectiveness [51]. However, transformational leadership's moderating role in entrepreneurial orientation and organizational commitment relationships has rarely been explored in the past. This present study investigates the moderation effects of transformational leadership to fertilize the body of literature on chosen factors.

2. Literature Review

2.1. Theoretical Foundation

The foundational theory for the present study is the "resource-based view (RBV)" developed by Barney [19]. The theory focuses on the resources as internal components of the organization and enhances the firm performance and competitiveness [20]. Previous literature posits that RBV is closely related to entrepreneurial orientation and its innovation abilities by identifying novel ideas, risk-taking, and proactive skills that enhance the SMEs' performance [8]. RBV significantly relates to the SMEs' performance because it assumes that internal capabilities are essential for firms' enhanced performance and competitive edge. The theory describes that the firms' internal resources include tangible assets, financial resources, organizational and human resources [19]. SMEs must utilize these resources innovatively to enhance performance [52].

2.2. Hypotheses Development

2.2.1. Relationship between Entrepreneurial Orientation and Organizational Commitment

Entrepreneurship has been categorized as an organizational trait, expounded primarily through entrepreneurial orientation. This advancement particularly followed the empirical course [53,54]. Numerous concepts of entrepreneurial orientation have amplified the existing literature [55,56]. The most projecting opinions are drawn by studies of Miller [57], Covin and Slevin [58]. The key difference in both schools of thought typifies entrepreneurial orientation built on a set of dimensions; for instance, "risk-taking, proactiveness, innovativeness, autonomy and competitive aggressiveness". According to Miller and Covin and Slevin, risk-taking, innovativeness and proactiveness are critical covariant factors for the existence of entrepreneurial orientation. However, Lumpkin and Dess broadened these covariant factors by adding autonomy and competitive aggressiveness, and linked these dimensions with the contextual dependences of the firms. Furthermore, Wales, Covin [59] suggested three incipient concepts of entrepreneurial orientation such as "entrepreneurial top management style, new entry initiatives and organizational configuration" (p. 2) to resolve these intersecting factors of entrepreneurial orientation [59]. However, Jambulingam, Kathuria [10] tested six dimensions of entrepreneurial orientation such as innovativeness, which means the willingness to support innovation, by developing organizational clusters taking entrepreneurial orientation as an intangible asset that ultimately enhances a firm's performance. Based on the recommendation of numerous studies and amid the context of the present study, risk-taking, innovativeness and proactiveness have been appointed as dimensions of entrepreneurial orientation [11–17]. Additionally, RBV significantly enhances SME's performance by considering the internal capabilities of the firm including financial, organization and human resources [19]. Soomro and Shah [7] adopted a deductive approach to investigate entrepreneurial orientation's effects on organizational commitment and found a significant association among the aforementioned variables [9]. However, the present study proposes within the context of Resource-Based View that the strengths (internal resources), including innovativeness, risk-taking, and pro-activeness capabilities, enables SMEs to enhance employees' commitment. Besides tangible assets, RBV supports intangible assets (human resources) to attract, train, develop and retain individuals and enhances their organizational commitment [60]. Therefore, on the basis of above discussion, the present study proposes that (see Figure 1).

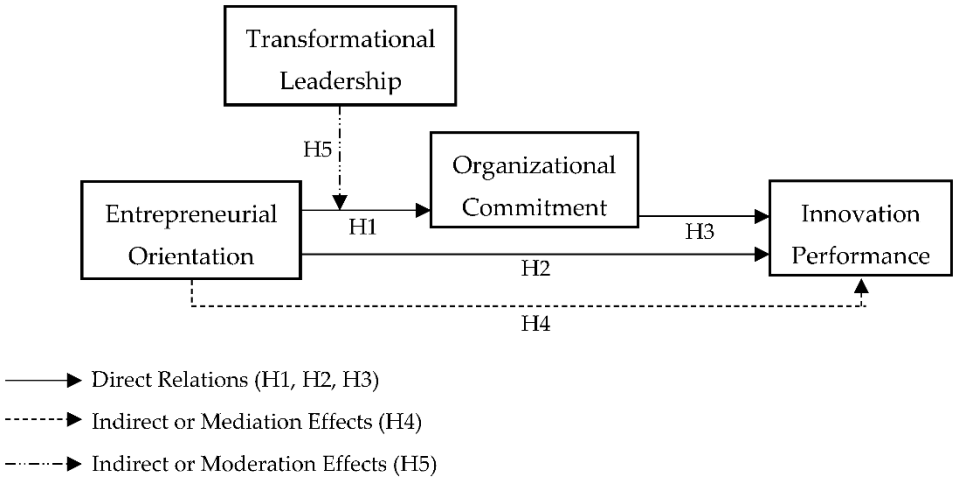

Figure 1. The proposed research framework.

Hypothesis 1 (H1). *Entrepreneurial orientation positively and significantly affects organizational commitment*.

2.2.2. The Relationship between Entrepreneurial Orientation and Innovation Performance

The development of creative ideas and behavior of firms leads to innovation performance. Innovation has several dimensions explained through the breadth and depth of innovation activities. Breadth includes the systems, strategies, processes, management, products and services. Whereas, innovation's depth comprises the significance and impact of innovation on the long-term profitability of firms [61]. Firms also aim at the administrative and technological innovation performance [61,62]. Technological innovation involves product and process innovation [61]. Product innovation contains the creation of innovative goods to fulfill customer requirements, while process innovation concentrates on changes to the current (i.e., prevailing) process. [63]. Product and process innovation have equal aptitude for enhancing effectiveness, performance, problem-solving, value addition and competitive advantage for firms [64,65]. Moreover, entrepreneurial orientation along with learning and marketing orientation was found to be positive concerning optimization of innovation and particularly, the business performance of SMEs. Besides the direct effects, these constructs also indirectly affected business performance through knowledge and innovation competencies of firms [66]. Isichei, Agbaeze [8] concluded a positive link between entrepreneurial orientation and firms' innovativeness. Preceding studies have found capricious effects of entrepreneurial orientation on firm performance. The literature also shows effects of related predictors on the innovation culture in SMEs, such as Abdul-Halim, Ahmad [67], who examined that organizational culture and learning significantly enhances the innovation culture in SMEs. The study of Isichei, Agbaeze [8] established the positive impact of innovativeness and proactiveness and the insignificant role of risk-taking on SMEs' performance. Moreover, past studies have examined entrepreneurial orientation's effects on innovation performance of SMEs [68,69], and the effects of entrepreneurial orientation on radical innovation [70]; however, much less is known about the aforementioned relationship in the context of SMEs working in developing countries using an RBV approach (entrepreneurial orientation's dimensions acts as internal resources).

Hypothesis 2 (H2). *Entrepreneurial orientation positively and significantly affects innovation performance*.

2.2.3. Relationship between Organizational Commitment and Innovation Performance

The phenomenon of organizational commitment is gaining popularity continuously in management studies. Organizational commitment refers to "the relative strength of an individual's identification with and involvement in a particular organization and can be characterized by a strong belief in and acceptance of the organization's goals and values, willingness to exert considerable effort on behalf of the organization and a strong desire to maintain membership of the organization" [36]. Meyer, Stanley [71] discussed three dimensions of commitment such as "affective commitment", which refers to "the employee's emotional attachment to, identification with, and involvement in the organization, continuance commitment as awareness of the costs associated with leaving the organization, and normative commitment referring to a perceived obligation to remain in the organization" (p. 21). The essence of organizational commitment lies within the truth that committed employees are highly involved in interlinked behaviors such as innovation performance [72], and enhance the performance and productivity of the firms [73]. Organizational commitment significantly correlates with organizational justice and employee sustainability [74], job behavior, employee fitness, welfare and turnover intentions [71], and especially, with innovation performance [68,69,75].

Firms need to employ satisfied, unstressed and committed employees to optimize organizational commitment, which leads to enhanced organizational innovation [76]. Being an essential element of organizational behavior, organizational commitment is multidimensional involving loyalty, willingness to make effort, value coherence and desire to keep members within the organization, which further improves individual and organizational innovation [72]. Moreover, employee commitment is linked with personal and organiza-

tional consequences [77,78]. For instance, [55], pro-activeness and innovativeness act as alternates and should be shared with the "commitment" to enhance the performance of firms. Likewise, Yeşil, Sözbilir [72] examined the positive effects of organizational commitment on innovation performance. Organizational commitment significantly enhances both product and process innovation (process innovation affects product innovation), which affects the functional performance of the organizations [79]. However, this study examines the effects of organizational commitment on innovation performance concerning RBV's intangible resources (commitment), affecting innovation performance.

Hypothesis 3 (H3). *Organizational commitment positively and significantly affects innovation performance*.

2.2.4. Mediating Role of Organizational Commitment

There is an interrelation between entrepreneurial orientation, organizational commitment and innovation performance. The same is found by Covin, Rigtering [55] in their study where entrepreneurial orientation and organizational commitment, jointly engendered, improved innovation performance. Commitment influences both individual and organizational outcomes [77,78]. When innovativeness, pro-activeness and commitment are combined, the organizational performance is optimized [55,72]. The functional performance of firms is also enhanced through the product and process innovation of firms [79]. Moreover, Soomro and Shah (2019) indicated the positive influence of entrepreneurial orientation on organizational commitment using a deductive approach of analysis. When linked with RBV, the internal resources of firms such as innovativeness, risk-taking abilities and proactive capabilities encourage firms to enhance organizational commitment. RBV also enhances the intangible assets such as human resources and to attract them, train and develop their abilities and retain them by enhancing their organizational commitment [60]. Focusing direct relationships among entrepreneurial orientation and organizational commitment [7,8], and organizational commitment and innovation performance [55,72], the present study proposes the intervening role of organizational commitment on innovation performance and proposes the relationships as follows (see Figure 1).

Hypothesis 4 (H4). *Organizational commitment positively and significantly mediates the relationship between entrepreneurial orientation and innovation performance*.

2.2.5. Moderating Role of Transformational Leadership

The four features of transformational leadership "idealized influence, inspirational motivation, intellectual stimulation and individualized consideration" significantly affect performance [54,80,81], innovation performance [82] and organizational commitment [83]. Engelen, Gupta [84] found that entrepreneurial orientation and innovation performance were moderated by transformational leadership using RBV, highlighting the importance of the transformational leadership's moderation mechanism on entrepreneurial orientation and organizational commitment. Transformational leadership inspires and attracts the followers by practicing moral ideas and values [85], and significantly enhances commitment [45]. Keeping in view RBV's tangible resources (transformational leaders as human assets) and intangible resources (transformational leaders' skills), the present study proposes that transformational leadership moderates the relationship between entrepreneurial orientation and organizational commitment. Therefore, we propose that (see, Figure 1).

Hypothesis 5 (H5). *Transformational leadership positively moderates the relationship among entrepreneurial orientation and organizational commitment*.

3. Materials and Methods

This study aimed to investigate three main research questions including (1) what are the direct effects of entrepreneurial orientation on organizational commitment and innovation performance, and direct effects of organizational commitment on innovation

performance of SME. (2) How organizational commitment mediates the relationship between entrepreneurial orientation and innovation performance of SMEs. 3) What is the level of moderating effects of transformational leadership on the relationship between entrepreneurial orientation and organizational commitment in SMEs.

3.1. Measures

The study adopted entrepreneurial orientation's three dimensions, namely risk-taking, innovativeness and proactiveness. The study adopted three items to measure innovativeness (e.g., "My firm shows the willingness to support creativity"), two items for risk-taking (e.g., "My firms takes the risk to venture into new unknown markets"), and two items for proactiveness (e.g., "My firm looks for market opportunities"), with $\alpha = 0.901$, adopted from the study of Lumpkin and Dess [86]. Four items were taken from the study of Wang and Ahmed [87] to measure innovation performance (e.g., "My firm has a highly responsive attitude towards environmental changes") with $\alpha = 0.922$. Seven items were adopted from the study of Ugaddan, Oh [88] to measure organizational commitment (e.g., "I feel a strong sense of belonging to my firm") with $\alpha = 0.940$. To measure transformational leadership, we adopted a five items scale from Bass and Avolio [89] (e.g., "My leader articulates a compelling vision") with $\alpha = 0.955$.

3.2. Population and Sampling

This study selected four significant SME sectors (services, manufacturing, high-tech and construction; one from each industry) as the study population. There are approximately 0.4, 0.6 and 1 million manufacturing, service and trading sector SMEs in Pakistan. We collected the data using the survey data collection method from September 2019 to February 2020 (in six months) with a time-lag of two months to elude common method bias (CMB), as recommended by Podsakoff, MacKenzie [90]. Primarily, we approached 1450 employees working in SMEs via personal visits and emailed them to share the survey, and for this purpose, we sent 2–3 soft reminders for every round. Before asking the variable's responses, we added a consent declaration, details about the nature of the research, and assured the respondents that their responses would only be used for academic research purposes and their confidentiality will be maintained using all predetermined protocols. In the first phase of data collection, data related to entrepreneurial orientation and demographic characteristics such as age, location, industry, and the number of SMEs' employees were collected. Data concerning organizational commitment, transformational leadership and innovation performance were collected in the second and third phases. A total of 1198, 1156, and 1126 responses were collected in the first, second, and third phases, respectively. However, 31 responses were rejected due to missing information. Thus, 1095 responses yielding a 75.5% response rate were further processed for data analysis [91]. To match the responses of three phases, we placed a computer-generated code on each response. The descriptive statistics showed that 81 (7.40%), 257 (23.47%), 331 (30.23%), 299 (27.31%), and 127 (11.60%) respondents were from SMEs aged from less than one year, 1–5 years, 6–10 years, 11–15 years and higher than 15 years, respectively. Moreover, the location of the SMEs was from Azad Jammu Kashmir, Punjab, Baluchistan, Sindh, Gilgit Baltistan and Khyber Pakhtunkhwa, with frequencies of 54 (4.93%), 561 (51.23%), 37 (3.38%), 59 (5.39%), 81 (7.40%) and 303 (27.67%), respectively. The descriptive analysis also reflects that 212 (19.36%), 677 (61.83%), 27 (2.47%) and 179 (16.35%) SMEs were from construction, manufacturing, high-tech and services industries. Finally, the number of employees in the SMEs within the ranges of 10 to 35, 33 to 99 and 100 to 250 employees were 311 (28.40%), 473 (43.20%) and 311 (28.40%), respectively (see Table 1).

Table 1. Descriptive statistics of Small and medium-sized enterprises' employees.

Controls	Range	Frequency	%
Location	Azad Jammu Kashmir	54	4.93%
	Punjab	561	51.23%
	Baluchistan	37	3.38%
	Sindh	59	5.39%
	Gilgit Baltistan	81	7.40%
	Khyber Pakhtunkhwa	303	27.67%
Age of SMEs	Less than 1 Year	81	7.40%
	1–5 Years	257	23.47%
	6–10 Years	331	30.23%
	11–15 Years	299	27.31%
	Higher than 15 Years	127	11.60%
Industry	Construction	212	19.36%
	Manufacturing	677	61.83%
	High-tech	27	2.47%
	Services	179	16.35%
No. of Employees	10 to 35 Employees	311	28.40%
	36 to 99 Employees	473	43.20%
	100 to 250 Employees	311	28.40%

3.3. Data Analysis

The present study used Smart PLS (3.2.8), a statistical tool to examine the data through partial least square equation modeling (PLS-SEM). The reason for choosing this analysis approach is based on the data/sample features and the moderation and mediation analysis. Similarly, this approach has gained much prominence in studies about human resource management, marketing and related fields [33,92–96]. Hair, Ringle [96] suggested using PLS-SEM to predict dependent variables' effects. Likewise, Davari and Rezazadeh [97] suggested that this method is suitable for predicting a group of equations simultaneously for the proposed research model and develops the relationship between variables. This study uses PLS-SEM as a verified reporting approach to conduct robust analysis in the management sciences domain. SEM is a second-generation multifaceted data investigation method that examines theoretically developed linear and additive casual relationships [98]. It allows researchers to examine the relationships between constructs. SME is considered as the best approach to measure the direct and indirect paths because it analyzes the difficult to examine and unobservable latent constructs. SEM consists of inner and outer model analyses, which examine the relationships between independent and dependent variables and relationships between latent constructs and their observed pointers. PLS focuses on variance analysis, which could be done using Smart PLS [99]. Therefore, this approach is selected for the present study.

4. Results

4.1. Measurement Model

The current study analyzed the measurement model approach to assess the reliability, composite reliability (CR) and average variance extracted (AVE) of the constructs. To measure the reliability, we have used Cronbach alpha (CA) and composite reliability. The results for CA and CR are presented in Table 2 for entrepreneurial orientation (0.901, 0.922), innovation performance (0.922, 0.944), organizational commitment (0.940, 0.952), and TL (0.955, 0.965) respectively. According to Hair, Ringle [96], CA and CR values should be higher than 0.70, and this study found the values to be in an acceptable range. We assessed the Fornell Larcker and heterotrait –monotrait (HTMT) ratio to test the discriminant validity [100]. The HTMT ratio has recently gained preference over Fornell and Larcker [101,102]. Fornell and Larcker's tests in Table 3 exhibit values greater than the correlations among the variables. The HTMT ratio results are lower than the 0.090 thresholds

(see Table 4). Additionally, we examined the convergent validity to obtain AVE values, and all the values were greater than the 0.50 threshold (for entrepreneurial orientation, organizational commitment, innovation performance and transformational leadership the AVE values were 0.628, 0.769, 0.810, and 0.846, respectively), as suggested by Henseler, Hubona [101] (see Table 2). Furthermore, we examined the variance inflation factor (VIF) to assess the problem of multicollinearity in the data. Aiken, West [103] suggested that the values of VIF must be <10, and this study found VIF values within the suggested range, depicting no issue of multicollinearity in the data (see Table 5).

Table 2. Measurement model.

Construct	Item Code	Loading	Outer Weights	CA	CR	AVE
Entrepreneurship orientation (EO)				0.901	0.922	0.628
	EO1	0.799	0.196			
	EO2	0.786	0.175			
	EO3	0.756	0.169			
	EO4	0.778	0.182			
	EO5	0.798	0.181			
	EO6	0.806	0.177			
	EO7	0.821	0.181			
Organizational Commitment (OC)				0.940	0.952	0.769
	OC1	0.906	0.188			
	OC2	0.877	0.184			
	OC3	0.885	0.198			
	OC4	0.879	0.196			
	OC5	0.864	0.189			
	OC6	0.85	0.184			
Innovation Performance (IP)				0.922	0.944	0.81
	IP1	0.912	0.283			
	IP2	0.885	0.262			
	IP3	0.91	0.284			
	IP4	0.892	0.282			
Transformational Leadership				0.955	0.965	0.846
	TL1	0.928	0.217			
	TL2	0.936	0.218			
	TL3	0.919	0.22			
	TL4	0.911	0.215			
	TL5	0.907	0.217			

Note: Average variance extracted (AVE); Cronbach's alpha (CA); Composite reliability (CR).

Table 3. Discriminant validity (latent variable correlation and square root of AVE).

	EO	IP	OC	TL
EO	0.792			
IP	0.459	0.900		
OC	0.423	0.702	0.877	
TL	0.304	0.683	0.756	0.920

Note: Entrepreneurial orientation (EO); innovation performance (IP); organizational commitment (OC); transformational leadership (TL).

Table 4. HTMT (heterotrait–monotrait ratio).

	EO	IP	OC
IP	0.503		
OC	0.459	0.752	
TL	0.327	0.727	0.797

Note: Entrepreneurial orientation (EO); innovation performance (IP); organizational commitment (OC); transformational leadership (TL).

Table 5. Saturated model results.

Construct	R2	Adj. R2	VIF	Q2	f2	SRMR
IP	0.581	0.580	1.219	0.442	0.035	0.058
OC	0.625	0.624	1.414	0.448		

Note: Variance inflation factor (VIF); predictive relevance (Q2); effect size (f2); standardized root mean square (SRMR); determination of coefficient (R2).

4.2. Assessment of Structural Model

We used the Smart PLS software to assess the structured equation model using 5000 bootstraps. According to Henseler, Hubona [101] and Cho, Hwang [104], the standardized root means square (SRMR) values should be lower than 0.08 (for a sample size greater than 100). Thus, we found a significant model fit for this study (0.058). The values of determination of coefficient (R2) should be >0.1 [105]. This study found that 58% variance occurred in innovation performance, explained by entrepreneurial orientation and organizational commitment, and 62.5% variance occurred on an organizational commitment by entrepreneurial orientation. Moreover, the value of Q2 should be higher than zero. Hence, this study's results were both within the significance level, and the study model's predictive relevance was achieved (see Table 5) [106]. This study's f2 value is 0.035, which falls within the suggested range by Cohen [107]. The study suggested that the f2 values of 0.02, 0.15 and 0.35 show the small, medium and significant impacts (see Table 5).

4.3. Structural Equation Modeling

The PLS-SEM findings show that (H1) entrepreneurial orientation has positive and significant effects on organizational commitment ($\beta = 0.277$, $t = 11.375$, $p = <0.05$). (H2) entrepreneurial orientation has positive and significant effects on innovation performance of firms with values of $\beta = 0.298$ $t = 11.146$, and $p = <0.05$. Moreover, (H3) organizational commitment has significant and positive effects on innovation performance ($\beta = 0.340$, $t = 8.432$, $p = <0.05$). Thus, we accepted the direct relationships of H1, H2 and H3. Moreover, the results show that (H4) the indirect effects of organizational commitment between the relationship of entrepreneurial orientation and innovation performance were positive and significant, with $\beta = 0.094$, $t = 7.096$, $p = <0.05$ (see Table 6). The past literature suggests that the indirect relation particularly includes a third variable, which acts as an intermediating variable in the relationships between dependent and independent variables. Technically, the effects of the independent variable (X) on the dependent variable (Z) are intermediated by a third variable (Y) [108]. Moreover, the direct effects of entrepreneurial orientation on organizational commitment ($\beta = 0.277$, $t = 11.375$), OC on IP ($\beta = 0.340$, $t = 8.432$) and entrepreneurial orientation on innovation performance ($\beta = 0.298$, $t = 11.146$) were positive and significant, and the indirect effects of organizational commitment between the relationship of entrepreneurial orientation and innovation performance were significant with $\beta = 0.094$, $t = 7.096$, which shows partial mediation in the model. The mechanism of the mediation process is as follows: Y is a variable affecting as a mediator if X affects Y, X affects Z, and Y significantly affects Z when controlling for X, and the effects of X on Z reduce significantly when Y is placed in the model simultaneously with X as an interpreter of Z [109,110]. Moreover, positive and significant direct and indirect relations probe partial mediation, while significant direct effects and insignificant indirect effects

result in full mediation between the independent and dependent variables [111]. Thus, partial mediation has occurred in this study and H4 was accepted (see Table 6, Figure 2). Furthermore, this study examined the moderation role of transformational leadership on the relationship between entrepreneurial orientation and organizational commitment. The findings exhibit a positive and significant effect of transformational leadership as a moderator with β = 0.096, t = 6.603, p = <0.05. Figure 3 explains that the interaction of transformational leadership (EO*TL) on entrepreneurial orientation and organizational commitment is positive, and higher levels of transformational leadership in the firms will increase the effects of entrepreneurial orientation on organizational commitment (see Table 6, Figure 3). Thus, we accepted H5 as well.

Table 6. Hypothesis constructs.

Effects	Relationships	Beta	Mean	(STDEV)	*t*-Value	Decision
		Direct relations				
H1	EO → OC	0.277	0.277	0.024	11.375 *	Yes
H2	EO → IP	0.298	0.299	0.027	11.146 *	Yes
H3	OC → IP	0.340	0.340	0.040	8.432 *	Yes
		Indirect or Mediating/Moderating				
H4	EO → OC → IP	0.094	0.094	0.013	7.096 *	Yes
H5	EO*TL → OC	0.096	0.096	0.015	6.603 *	Yes

Note: * p < 0.05, Entrepreneurial orientation (EO); innovation performance (IP); organizational commitment (OC); transformational leadership (TL).

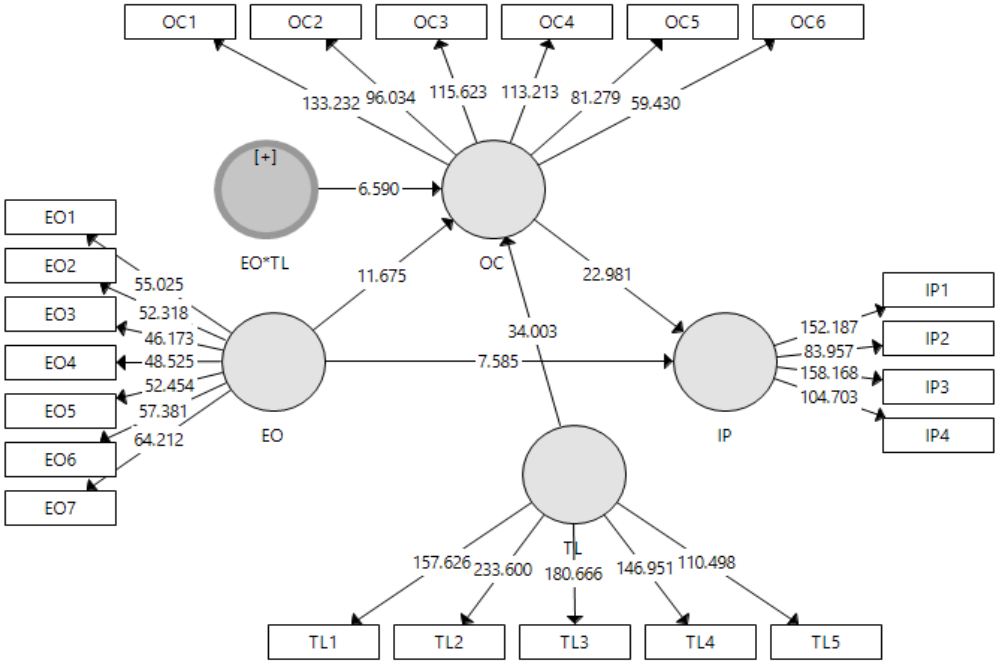

Figure 2. PLS-SEM showing positive relationships in variables.

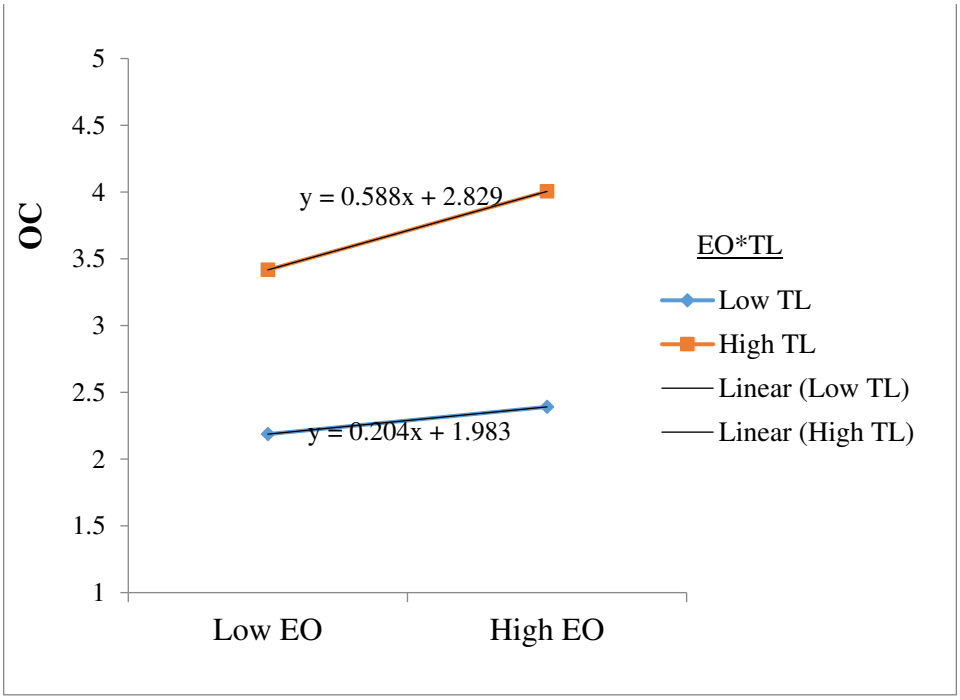

Figure 3. Interaction of TL between the relationship of EO and OC.

5. Discussion

The present study examined the mediating and moderating effects of organizational commitment and transformational leadership on innovation performance triggered by entrepreneurial orientation within the SMEs sector of a developing economy. In line with the past studies, entrepreneurial orientation positively affects organizational commitment [7,9,59,60], and entrepreneurial orientation significantly enhances innovation performance [8,61–63,65,68,75] through risk-taking, innovativeness, and reactiveness. Moreover, the present study demonstrates the nature of the relationship among innovation performance and organizational commitment. Findings exhibit that belongingness and emotional affiliation enhances the commitment of employees to their firms. It is further verified that sense of belongingness and emotional attachment (organizational commitment), enhances SMEs' innovation performance [55,72,77–79].

In the modern world of fierce competition among SMEs, entrepreneurial orientation leads to the success of firms by enhancing their innovation performance. Particularly, firms need to maintain readiness to enhance innovation and experiments to launch innovative products and services in the market to meet performance standards by supporting the novelty of research and development of new processes. Firms' abilities to take risks to enter into evolving markets by investing substantial resources enable them to innovate. In doing so, SMEs should look into new market opportunities by assessing future problems and preparing for needed change [86]. Alongside the entrepreneurial orientation's developmental role, organizational commitment plays a leading mediation role in SMEs' entrepreneurial orientation and innovation performance. The emotional attachment and sense of belongingness of employees to remain with their firm enhance their affective commitment. The measure of organizational commitment also includes employees' moral obligation of remaining with the firm for a longer duration, and not leaving the firm when offered a better job position elsewhere. Moreover, employees feel that a lot will change in their lives if they leave their current firms, and the level of difficulty for being detached from the current employer enhances their organizational commitment [88]. It is hard for the employees to achieve goals of entrepreneurial orientation and higher levels of organizational commitment without the leadership of the firm. In this regard, transformational leadership provides a best-fit for enhancing the process of entrepreneurial

orientation and organizational commitment towards innovation performance through providing compelling vision, assurance of goal attainment, inventive problem-solving, training and coaching and developing a strong sense of purpose [89]. All these factors substantially help in improving the highly responsive attitude of firms concerning the product and services innovation, improvement in manufacturing processes and lowering the production costs [87]. The present study examined the positive effects of all these critical characteristics on innovation performance.

The results indicate that organizational commitment has a decisive mediating effect between the relationships of entrepreneurial orientation and innovation performance. Findings indicate that entrepreneurial orientation enhances innovation performance significantly using RBV [55]. The dimensions of organizational commitment, such as continuance, normative and affective commitment, enhance innovation performance. Moreover, the results indicate the combined effects of entrepreneurial orientation and organizational commitment on innovation performance. Additionally, this study uniquely examined the mediating role of organizational commitment between the relationship of entrepreneurial orientation and innovation performance [55]. Third, this study focused on the moderating role of transformational leadership, based on its characteristics such as leader's skills to design appealing visions, focus on goal setting and achievement, indulgence in coaching, training and development, creative problem-solving skills, and developing a complete sense of purpose [89], enhancing the link between entrepreneurial orientation and organizational commitment [7,9,52,60] and innovation performance [5,8,10,18,20,22,27,28,70,75]. Aimed at examining the direct effects of transformational leadership on innovation performance [82] and organizational commitment [83], past studies suggested the increase in performance [54,80,81]. The moderating role of transformational leadership on entrepreneurial orientation and innovation performance's relation was found to be positive [84]; therefore, this study examined the transformational leadership's moderation mechanism on the relationship between entrepreneurial orientation and organizational commitment. Thus, the results concluded that a higher level of transformational leadership of SME managers enhances the relationship between entrepreneurial orientation and organizational commitment.

Finally, the study embedded RBV into transformational leadership, where transformational leaders or human assets represent SMEs' tangible resources and leaders' particular skills as intangible assets. Thus, both kinds of resources are essential to achieve the higher impacts of entrepreneurial orientation on organizational commitment through the moderation role of transformational leadership. On the other hand, organizational commitment also has a significant link with RBV. The effective, continuance and normative commitment of employees refer to the firms' intangible resources, enhancing organizational commitment and, ultimately, the firms' innovation performance. Additionally, RBV indulges the innovation process, where both process and product innovation heavily involve RBV. Innovation and innovation performance depend on the tangible (transformational leaders, technology and resources) and intangible resources (skills of transformational leaders, and level of commitment of employees) of the firms and rely on the interlinked mechanism such as EO effects on organizational commitment and innovation performance.

5.1. Theoretical Contributions

This study has several theoretical contributions. First, the findings contribute to the literature on entrepreneurial orientation. This study validates that dimensions of entrepreneurial orientation such as innovativeness (SMEs willingness to support innovative ideas, experiments for product and service development and novel research and development), risk-taking (risk-taking capability to enter new markets and investment on new ventures) and proactiveness (SMEs' strive to explore new opportunities and pro-active approaches to issues, needs and changes) have a significant impact on organizational commitment [7,9,52,60] and innovation performance [5,8,10,18,20,22,27,28,70,75].

5.2. Practical and Managerial Implications

This study offers several practical and managerial implications based on entrepreneu rial orientation's impacts on the optimization of innovation performance. First, entrepreneu rial orientation (innovativeness, proactiveness, and risk-taking) helps in achieving SMEs' innovation milestones. The results show that human resource managers can utilize the entrepreneurial orientation's characteristics to enhance the firm's innovation performance while focusing on RBV philosophy [8,70]. Second, the firms should use risk-taking, innovativeness, and proactiveness to develop internal innovation performance strategies. Third, leaders should help their firms to practice these characteristics to enhance the firm's innovation performance. Leaders should also critically assess the fact that innovative and proactive activities in the firm enhance the level of commitment within the SMEs; thus, they should practice it rigorously. Lastly, the managers should focus on transformational leadership's vital role to optimize the effects of entrepreneurial orientation on organizational commitment with the help of transformational leadership skills such as developing a strong sense of purpose, coaching and training, and formulating compelling visions for their subordinates.

5.3. Limitations

Consistent with other research studies, the current study also has some limitations. We deliberately aimed at reducing common method bias using the time-lag data collection method, which averts the unprompted interventions. Future research should develop causal links through longitudinal research models. Being a developing country, SMEs in a developing economy generally avoid high risk-taking and proactive approaches towards uncertain situations. Future studies should measure the level of risk-taking capabilities of SMEs. Moreover, keeping in mind the large number of SMEs in Pakistan (600,000 services, 400,000 manufacturing and one million trade sector units [112], future studies should enhance the sample size categorically to enhance the study scope. Finally, future studies may consider other types of leadership styles are moderators such as passive leadership [113], parental leadership [114] or servant leadership [115].

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki. The review board of Jiangsu University exempted the research for ethical approval, as it is a survey-based study. The study obtained the consent of the employees working in the SMEs and they filled the questionnaires willingly.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original data is provided by all the authors. If there are relevant research needs, the data can be obtained by sending an email to the corresponding author. Please indicate the purpose of the research and the statement of data confidentiality in the email.

Conflicts of Interest: The authors declare no conflict of interest.

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A Study on Emerging Management Practices of Renewable Energy Companies after the Outbreak of Covid-19: Using an Interpretive Structural Modeling (ISM) Approach

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Abstract: The role of management practices in the success of renewable energy organizations is not negligible because management practices are the backbone of any organization. Energy organizations are facing drastic environmental issues; therefore, the sector inevitably requires environment- friendly production, which is only possible through the deployment of concurrent management practices because sluggish management practices lead to dormancy and inadequate performance. This study investigates the emerging management practices that will enable the renewable energy sector to fulfill the current demands of the market, especially after the outbreak of the Covid-19 pandemic. This research deployed a qualitative research methodology that is grounded in the interpretivism research paradigm. Interpretive structural modeling (ISM) was applied due to the extent of its logical thinking, and its ability to address complex issues and disseminate results precisely. Data were collected through primary (structured and unstructured interviews) and secondary sources (literature reviews published in the last 10 years). Interviews of top- and middle-level managers working in the renewable energy sector of developing countries were conducted. The findings of the study postulate that the implementation of knowledge management practices and policy changes are the key influencing factors to achieve sustainable organizational performance. Decentralization also has the potential to influence and navigate the organizational performance of energy companies. The findings of the research advocate innovative practices for the energy sector that influence organizational performance. The qualitative findings of the study suggest that emerging practices, including knowledge management practices and decentralization, may proliferate organizational growth and development. The novel framework of the study implies that organizations should work progressively in deploying emerging management practices such as establishing a central response hub to avoid delays under the umbrella of resilience leadership.

Keywords: renewable energy; emerging management practices; knowledge management; decentralization; sustainable organizational performance

1. Introduction

The current and rapidly changing competitive environment presents potential opportunities and threats for the renewable energy sector. Renewable energy is the strongest pillar of the energy system and has the potential to use emerging management practices [1]. These factors imply that organizations should adopt emerging management practices to respond competitively. The literature suggests that various management practices are utilized by different firms to increase their outcome and cope with changing market trends. Other organizations try to replicate these practices and resources to improve their productivity. According to Michael [2], for every organization, motivated and creative human capital is the only resource of the organization that cannot be imitated, replaced, or reproduced. An organization's crucial responsibility is to enhance customers' experience and society at large through existing human resources. Hamel [3] asserted that emerging management practices, which were initiated at the start of the 19th century, have reached their limit of improvement and a new paradigm is now necessary for the era of the 20th century to meet the challenges of an unpredictable world. After the outbreak of Covid-19, it became inevitable to address management issues for organizational growth. Large organizations change strategies by incorporating their organizational resources, which have been built over time.

After the pandemic, the entire structure of organizations changed, whether it is its internal structure or external working environment that needs new practices to handle organizational affairs efficiently. Emerging management practices do not require the transformation of the entire structure of the organization; rather, they require turning the lens toward the working procedures of firms. Organizations, especially innovative organizations, may not last unless they apply unique ways of operationalization according to their dynamics and structure, which is only possible through inculcating an efficient knowledge management process [4]. Therefore, it is important to analyze in depth how to implement emerging management practices, especially knowledge management and decentralization phenomena, to handle the challenges emerging during and after Covid-19 to improve sustainable organizational performance [5].

The literature on management practices [6–8] explores that while applying emerging management practices, a grounded and knowledge-based point of view is needed. Adhikari [9] suggested that all strategies and practices must be accompanied by knowledge management to gain a competitive advantage in the modern corporate world. To compete with ever-changing situations around the globe, companies noticed that knowledge in an organization is continuing asset. According to Hustedt, Bohl [10] it has now been accepted by organizations that knowledge is the true source of power and will increasingly become so as the 21st century progresses. Natek and Zwilling [11] reported that the corporate world is considering knowledge management processes—acquisition, dissemination, and implementation—as a foundation of its processes. The tentative support of decentralization in organizational growth across sectors is widely noted and discussed by different researchers [12–14]. The impact of decentralization triggers increased motivation, sense of ownership, increased employee productivity, and return of net assets, etc. According to Deliotte [15], many innovative organizational practices emerged in response to Covid-19, such as the central response office, partnering with stakeholders, blended learning with a new focus, and, ultimately, by shifting operations to digital mechanisms. Additionally, leadership readiness to accept change, which consequently leads to the invention of management practices, is important for organizational growth [16].

The situation in developing countries during the pandemic is worse, and organizations are striving to seek emerging practices to survive and grow. The renewable energy sector in developing countries is gearing up, and companies are heavily investing in this sector due to the high demand for renewable energy. Hence, this research attempts to explore the challenging problems of the energy sector in emerging economies and contribute theoretically by adding new literature on (1) emerging management practices (2) decentralization and (3) knowledge management, with its application in the current setup of the renewable

energy sector. The research also delivers the insight of a "knowledge-based perspective" that suggests that policymakers design policies according to modern requirements of the current era. Pakistan is the sixth-largest populous country, with an integral geographical location on the continent of Asia. It requires sufficient energy resources to meet its industrial, commercial, and household demands to keep its growth and development. The potential of renewable energy in Pakistan is above 50,000 MW. The installed capacity of renewable energy during the fiscal year 2019–2020 increased by 6% as compared to the previous year. This indicates that developing countries are heading quickly towards renewable energy production and consumption. The renewable energy sector, especially solar, is growing exponentially, but meanwhile faces a different problem concerning durability [17]. This is because the demand for neat and clean energy is increasing over time [18]. The total electricity generation capacity of Pakistan has reached 35,972 MW. The contribution of renewable energy, including wind, solar and hydel, is approximately 8% in total generation capacity. However, as a matter of fact, despite being bestowed with abundant resources and enormous ways of energy generation potential, the country is unable to meet its energy demands and is facing an acute energy shortfall [19,20]. Hence, this study contributes uniquely by addressing energy issues in developing countries, specifically in Pakistan, and its findings should be reasonably prolific for practitioners and policymakers in renewable energy companies in developing countries.

2. Literature Review

For business survival during the uncertainty brought by Covid-19, firms have been forced to develop new management practices that are accessible and suitable for the current era. A conscious path of transformation in operations is much needed to help organizations minimize the critically alarming and ongoing effects of Covid-19 that have been unfavorable for people, operations, and overall business activities, especially in the energy sector.

2.1. Knowledge Management

Following Rubenstein-Montano, Liebowitz [21], knowledge has been observed widely in Western philosophy due to its significant contribution in strategic decision making since the classical Greek era. More recently, scholars proclaimed that for effective strategic actions, organizations may increase their capacity through knowledge management [22,23]. Moreover, they asserted that knowledge can be viewed in variant forms such as the capacity of acquiring knowledge, access to information, state of mind, and ways to process the information. Handling knowledge has become an emerging tool and asset for organizations in recent years. Researchers have developed a comprehensive knowledge management system (KMS) through individual knowledge management and organizational knowledge. A resource-based view (RBV) laid down the foundation for these concepts, where firms develop a proper KMS process as initially presented by Penrose 1959 and extended by [22,24,25]. Tacit and explicit streams of knowledge were defined by Natek and Zwilling [11] as essential for knowledge acquisition. Furthermore, an emotionally intelligent organization also leads to knowledge-sharing behavior [26]. Tacit knowledge comprises technical and thinking elements that are exposed through actions, experiences, and specific backgrounds. It comes under the classification of "cognitive" knowledge: consisting of viewpoints, paradigms, beliefs, and mental maps. López-Nicolás and Meroño-Cerdán [27] suggested that the creativity of any organization can be enhanced through tacit knowledge, while explicit knowledge can be enriched through informal ways of acquiring information. To understand and develop action-oriented strategies for an organization, it is better to first understand the available organizational sources of knowledge.

2.2. Decentralization

Decentralization is a necessary practice to be implemented as the main integral element for any organization, especially during the initial growth phase. Decentralization is characterized as empowering your subordinates to take decisions on their own to save time and to avoid delays of decisions. This concept has achieved success in the developed world but is less realized in the developing world. Therefore, the objective of this study is to explore decentralization as an emerging practice that can have an impact at the corporate level in developing countries [28,29]. It is also argued that the implications of implementing decentralization include the complexity of the process and ambiguity in the roles of employees at a higher level [30]. This phenomenon is still misunderstood because of prevailing ambiguity about its mechanisms and strategies. The contextual setting of the country is the main factor that contributes to the process of decentralization [31,32]. Universally, it is agreed that the criteria of decentralization are complex and its measuring tools are scarce. The power and its delegation are complex phenomena due to its susceptible measurable categories and substantial attachment to positions. The measuring criteria of the decentralized institution should be different from that for those that are highly centralized. According to Vengroff and Salem [33] in any country, the relative quality of decentralization (D) is measured through the criteria of

$$D = f(S,\ I, C)$$

where "S" denotes the function of range; "I" represents the intensity and "C" represents a commitment. Additionally, they asserted that decentralization is influenced by the opportunities available to participants, geographical area, population, and substantial power scheme. Decentralization is known best for accountability, democratization, self-empowerment, reducing conflict, and providing civic responsibility [34].

2.3. Emerging Management Practices

Emerging management practices are an ever-evolving notion and continue to change according to contextual factors. The operations of organizations dramatically changed after the appearance of Covid-19. Companies with a flexible working environment, rather than those companies that are rigid and reluctant to adopt new management practices, showed their sustainability. The debate about emerging management practices, specifically after the pandemic, is multifaceted and yet has not reached a final conclusion. It is estimated that the GDP of developed economies will fall to 6% and developing economies may face negative growth. Covid-19 is not only a health dilemma but also signifies an economic crisis that will lead to the sluggish performance of organizations and ultimately to unemployment and poverty [35]. Karmaker, Ahmed [35] emphasized that strategies like collaboration with one's stakeholders and making them partners in business affairs are the emerging trends during this challenging period. Additionally, they proclaimed that sustainable supply chain procurement is becoming more common because standalone organizations cannot survive. Deliotte [15] advocated the philosophy of respond, recover, and thrive (RRT) as an immediate remedy to sluggish performance. Resilience leadership can inspire employees to help them to lead in difficult and unexpected days. Such leadership ensures that all key stakeholders are critical contributors, and their health and safety concerns are put forward as a priority. Before the pandemic, customized and delegated services were encouraged; however, keeping in mind the present dilemma, responding centrally to the designated problem by seeking endorsements across all departments it is now highly valued. Based on a careful investigation, the following concepts are derived from the literature. The key issues are identified through the literature and are depicted in Table 1 below.

Table 1. Identification of key issues through systematic review.

Serial #	Key Issues/Factors	References
1	Understanding knowledge management (KM) narrative	[4,8,11,22,36]
2	Emerging Management practices	[3,15,19,35]
3	Decentralization mechanisms	[12,14,30,32,34]
4	Effect of Decentralization on owner's control	[10,12,13,29]
5	Implementation of KM and policy change	[9,15,21,24,27,35]

2.4. Knowledge-Based Perspective as a Theoretical Lens

Penrose [37] proposed a resource-based theory that focused on rare, inimitable, valuable, and trustworthy resources as a foundation for any organization that is needed for sustaining long-term growth. Later on, this approach was highly admired, laid the foundation for a knowledge-based perspective, and cited [24,38,39]. The knowledge-based perspective indicates that tangible resources can yield results only if they are aligned and coherent with each other. Completing this process of aligning tangible resources depends on to what extent the firm is knowledgeable. The acquisition and retention of knowledge heavily rely on culture, policies, strategic systems, routines, and documents [7,8,22,40]. Nevertheless, individual characteristics are also important triggers. Thus, KMS is the best strategy to use to apply decentralization concepts organization-wide. In aggressive competition, knowledge management is used as a weapon for sustainable development to compete and grow [41]. Additionally, sustainable organizational performance can be increased through proper mechanisms of storing, retrieving, and using a firm's knowledge. On the whole, organizational processes and performances can be increased through knowledge. Due to its multiple facets and heterogeneity, it is confirmed that KMS can be applied in the energy sector particularly. Thus, this study attempts to explore the KMS mechanisms in renewable energy companies. The variable identification through literature is shown in Table 2.

Table 2. Interpretive structural modeling (ISM) reference table; variable identification.

Serial #	Key Issues/Factors	Variables	References
1	Understanding KM narrative	V1	[4,8,11,22,36]
2	Emerging management practices	V2	[3,15,19,35]
3	Decentralization mechanisms	V3	[12,14,30,32,34]
4	Effect of Decentralization on owner's control	V4	[10,12,13,29]
5	Implementation of KM and policy change	V5	[9,15,21,24,27,35]

3. Methods, Materials, and Research Tools

Since the objective of the study was to explore emerging management practices in-depth in renewable energy companies hence, a qualitative methodology was considered most suitable and appropriate in this context. The qualitative approach was deployed in the research by using interpretive structural modeling, hereafter referred to as "ISM". ISM is more appropriate when the description and exploration are required through interviews and literature. ISM is more advantageous than other techniques because it helps to draw the research model of the study. Although ISM has been used for a couple of decades, it is still among the most widely used research techniques in qualitative research design. Lee, Saunders [42] indicated that quicker and real experiences can only be measured through qualitative research methodology. The answer to the untapped and unexplored phenomenon of emerging management practices is not possible through any customary tool except collecting data through interviewing and observing managers who are working in the system, especially in the context of developing countries. For a deeper understanding of the phenomena, a subjective approach to understand a reality where little information is known is considered the best approach [43]. This study used a systematic literature review for the initial concept and variable identification. Later, these concepts are authorized

by experts and practitioners from the renewable energy sector. ISM is a more helpful modeling technique that is used as a tool for logical thinking, approaching complex issues carefully, and then disseminating the results to others [44,45]. The ISM process consists of the following (1) Identification of key issues/variables such as the contribution of emerging management practices, KM, and decentralization toward sustainable organizational performance. (2) Identification of relationships between variables using the structural self-interaction matrix, hereafter denoted as "SSIM". (3) Developing a reachability matrix by converting the SSIM. (4) Testing transitivity in the next step. (5) Deriving model levels using the reachability matrix. (6) Translating the relationship and drawing an ISM model. (7) Reviewing the inconsistencies and revising accordingly. The structural flow is depicted in Figure 1.

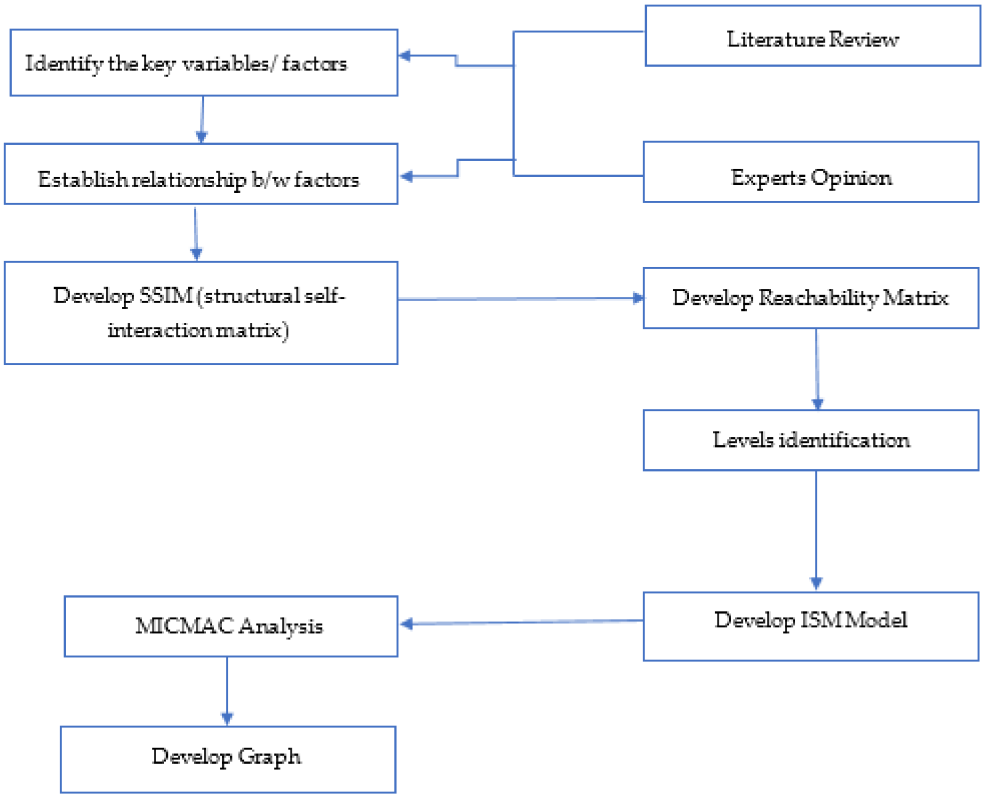

Figure 1. Structural Flow of ISM.

3.1. Data Collection

The data in this study was gathered through primary and secondary sources. For primary sources, top- and middle-level managers with a minimum of two years of experience and substantial information about the variables of the study were recruited. The interview questions along with the consent form were delivered to them before the interview so they were better informed about the concepts. In the secondary form of data, the information was collected through rigorous literature related to the topic. Both forms of data helped to finalize the variables of the study.

3.2. Sampling Strategy

Aligned to the qualitative research paradigm used for this study, a non-probability sampling strategy was used. It is suggested by Sadler, Lee [46] that when the population is narrowly defined, a snowball sampling strategy is the best strategy to reach the targeted population. Snowball sampling involves a researcher reaching a successor respondent through a chosen respondent. Hence, this study used a snowball sampling strategy where

potential respondents were recruited with the help of existing respondents. A total of 13 respondents was recruited to obtain their responses on the research topic.

3.3. Findings

3.3.1. Demographic

The demographic profile of respondents depicts the role of women in the renewable energy sector because women's participation is minimal in developing countries. Hence, gender participation, along with other demographic factors including age and experience, are shown in the demographic section (Table 3).

Table 3. Demographics.

Participants	Sex	Experience	Age
P1	M	4	40–49
P2	M	13	20–29
P3	M	5	30–39
P4	M	3	30–39
P5	F	4	20–29
P6	M	4	20–29
P7	M	7	30–39
P8	F	3	20–29
P9	F	2	20–29
P10	M	4	30–39
P11	F	8	30–39
P12	M	3	30–39
P13	F	7	30–39

Table 3 denotes that 62% of the total sample were male participants while 38% of participants in the study were female. In terms of age, 54% of participants were 30–39 years old while 38% were 29–30 years old, the second dominant age bracket. The study also indicates the education level of participants because education is the most important element for participants of this study. Of all participants, 69% had a master's degree while 3% had postgraduate degrees and 2% received a graduate degree. In total, 90% of companies selected for data collection were international, while only 10% percent of the sample were local companies.

ISM methodology provides that the structural self-interaction matrix (SSIM) is developed on the element set and the contextual relation based on a pairwise comparison of variables. These are developed through the opinions of experts and academicians as this is the best way to examine the relationship between variables, which ultimately strengthens the objective(s) of the study. The factors of knowledge management and decentralization, on the entire list, are embedding factors towards organizational success. The background and literature for these factors were explained to the experts, and the experts were asked to consider the adequacy of the concepts. Using Table 4, the SSIM matrix was designed as follows.

The next process was to convert the SSIM into a reachability matrix (RM). In this process, the matrix was converted into binary codes (1, 0). V, A, X, and O were replaced by 1 and 0 according to the VAXO rule. The following rules were applied in the process to derive a reachability matrix, as shown in Table 5.

- Where i and j in SSIM is "V", then insert the value of i and j as "1" and then j and i as "0" in the reachability matrix.
- Where i and j in SSIM is "A", then insert the value of i and j as "0" and then j and i as "1" in the reachability matrix.
- Where i and j in SSIM is "X", then insert the value of i and j as "1" and then j and i as "1" in the reachability matrix.
- Where i and j in SSIM is "O", then insert the value of i and j as "0" and then j and i as "0" in the reachability matrix.

Table 4. Structural self-interaction matrix (SSIM) matrix.

i → j	V1	V2	V3	V4	V5
V1	1	A	V	X	V
V2		1	V	O	V
V3			1	V	V
V4				1	V
V5					1

To determine the direction of the relationship, the VAXO rule was applied based on the dependence of two factors, i and j. For making SSIM Table 4 possibilities were considered. Figure 2 provides further details.

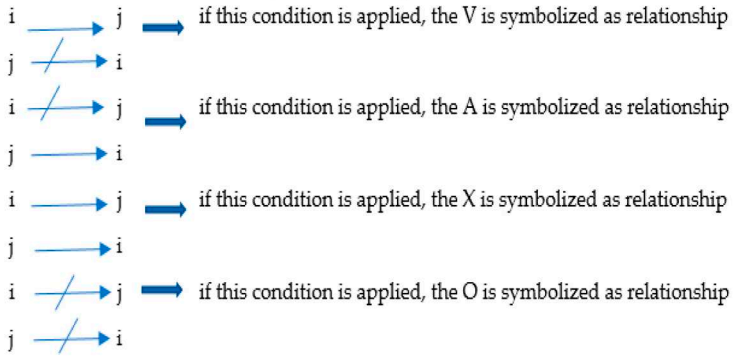

Figure 2. Explanations for the applied conditions.

Table 5. Reachability matrix.

i → j	V1	V2	V3	V4	V5	Driving Variables
V1	1	0	1	1	1	4
V2	1	1	1	0	1	4
V3	0	0	1	1	1	3
V4	1	0	0	1	1	3
V5	0	0	0	0	1	1
Dependent Variables	3	1	3	3	5	15

The next step was to develop a transitivity set and the identification of levels. In this process, intersections and reachability columns were matched; the best matching was identified as level 1 and holds the top level in the hierarchy, and so on. In this case, V5 (sustainable organizational performance) was the first level for the ISM framework. After this process, V5 was removed in the next iteration in both columns, and we could reach the next level until the level of each factor was obtained. Table 6 indicates the level identification for each set.

The structural framework was drawn from the reachability matrix and intersection set. The i to j criteria of the relationship was demonstrated in the ISM framework in Figure 3. This Figure indicates that the implication of KM and policy change V2 had great significance for sustainable organizational performance, as it occupied the basic level of the ISM hierarchy. Sustainable organizational performance V5 was the influence factor on which emerging management practices depend, as it appeared at the top level of the ISM framework. The complete framework is shown in Figure 3.

Table 6. Level identification.

i → j ↓	Reachability Set	Antecedent Set	Intersections Set	Level Identification
V1	1,3,4,5	1,2,4	1,4	Level two
V2	1,2,3,5	2	2	Level four
V3	3,4,5	1,2,3	3	Level three
V4	1,4,5	1,3,4	1,4	Level two
V5	5	1,2,3,4,5	5	Level one

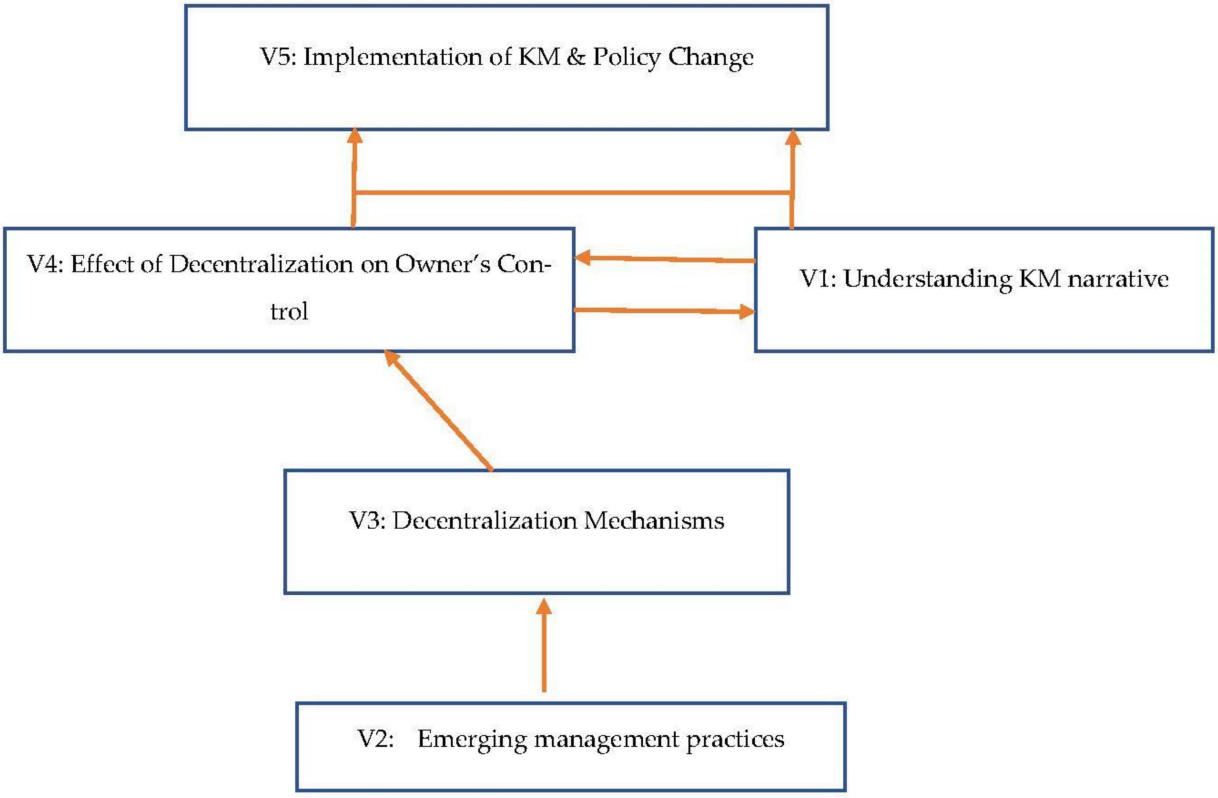

Figure 3. ISM framework.

3.3.2. MICMAC Analysis

"Matriced' Impacts Croisés Multiplication Appliquée á un Classement" also known as, "cross-impact matrix multiplication applied to classification", is abbreviated as MICMAC. The basic objective of utilizing MICMAC analysis is underpinned in analyzing the dependence power and drive power of factors. The principle of MICMAC is derived through the multiplication properties of matrices and it is performed to identify the key factors that drive a system in various categories. Based on their drive power and dependence power, the factors were classified into four categories, i.e., autonomous factors, linkage factors, dependent, and independent factors. Hence, the MICMAC analysis was utilized to classify the barriers. For classification, a cross-impact matrix was applied in MICMAC. It has two powers: (1) driving power on the vertical axis and (2) dependent power on X-axis. This analysis was further divided into four main categories: autonomous, linkage, independent or driving, and dependent factors [47]. Table 7 and Figure 4 depict the MICMAC analysis of the study.

1. Figure 4 shows that none of the variables falls in the "autonomous" cluster, which indicates a weak driving and ultimately dependent power.
2. Variable two, "implementation of KM and policy change", falls in the independent or driving cluster. This indicates that this variable can lead other variables. Furthermore, it also has an indication that organizations need to critically focus on this factor.
3. In this study, three variables (V1, V3, and V4) lie in cluster three, named the "linking" cluster. It shows that these variables have a strong bonding with other variables, especially with the dependent variable. It can be assumed that it is vital to focus on these variables for sustainable operations of the organization.
4. Variable five falls in cluster four, named the "dependent' cluster". It shows that this variable is influenced by all other variables and is sensitive. Any change in other variables will have a greater impact on this variable.

Table 7. Dependent and driving variables for the cross-impact matrix multiplication applied to classification (MICMAC) analysis.

Factors	Variables	Driving Variables	Dependent Variables
Understanding the KM narrative	V1	4	3
Emerging management practices	V2	4	1
Decentralization mechanisms	V3	3	3
Effect of decentralization on owner's control	V4	3	3
Implementation of KM and policy change	V5	1	5

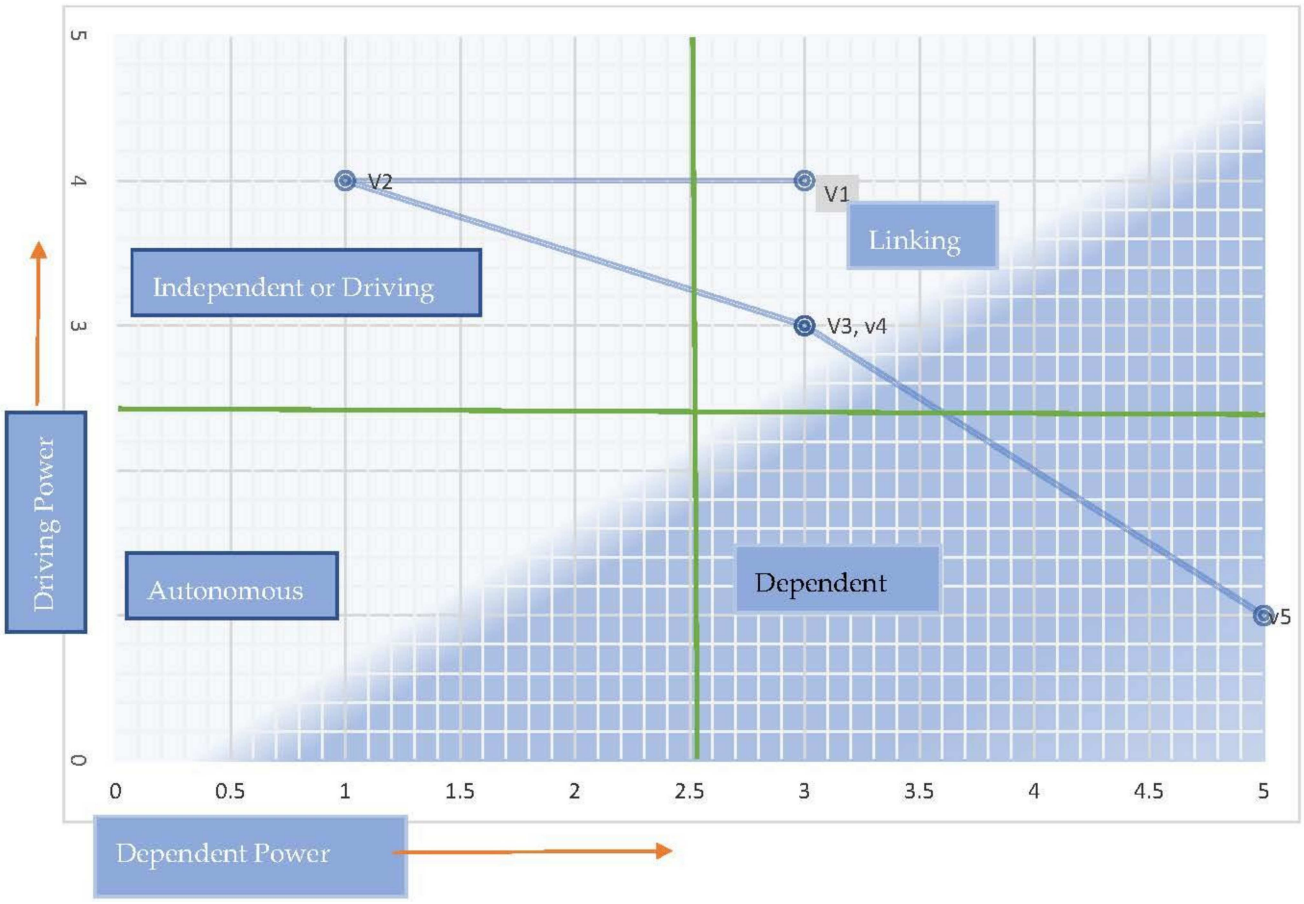

Figure 4. MICMAC analysis of the study.

4. Discussion

The research findings indicate that knowledge management, central response control, resilience leadership, and decentralization are diluted in the basic operations of energy organizations especially after the emergence of Covid-19, and such practices are also found in recent studies [15]. The results of the study indicate that emerging management practices such as resilience leadership and a central response center are the baseline to implement the concepts of knowledge management and decentralization. Similar ideas have also been provided by different researchers in the past: namely, decentralization (John and Chathukulam [30]) and emerging management [4,15,36,48] are weak in the energy sector of developing countries. However, in many cases, the companies are aware of the importance of these subjects. Moreover, the analysis of the interviews suggests that top management of organizations are willing to work on emerging management practices, because this concept is fundamental to organizational growth and innovation, but are unable to thoroughly work on them due to certain restraints. The analysis also shows that organizations are unaware of the rewards of these concepts in many cases. The participants of the study demonstrated their readiness to implement these concepts, provided that the institution provides them full support, resources, orientation, and training about emerging management practices, KMS, and decentralization mechanisms.

Emerging management practices are fundamental and are extremely necessary to firms' effectiveness and efficiency. The notion of knowledge is underpinned in the novel practices of management, and the importance of knowledge is also discussed in the previous literature [8,23]. The study reveals that capacity enhancement of an organization is possible through the implementation of knowledge management, which will ultimately lead to strategic actions and organizational competitiveness [23]. The findings of Santoro, Vrontis [22] also support the results of the study regarding the implementation of knowledge management: that it makes an organization unique, creative, and different from other organizations The evidence in Figure 3 indicates that the "implication of knowledge management and policy" is a dependent factor and is influenced by management practices. The MICMAC analysis of the study indicates that KM and policy change lie in the independent quadrant of the graph. Hence, these factors deeply influence organizational practices. The KM practices are mutually agreed by all respondents, but its understanding and implementation processes are applied differently: government support, organizational support, financial resources, time, and interest of the owner are the main barriers to the application of these practices. In the development of emerging management practices, KM strategies and policies are supported assertively as key drivers.

In developing countries, the debate about decentralization for empowerment and better decision making is attracting the interest of researchers and practitioners. However, there is a dearth of methods, and these need more attention for the effective handling of organizational affairs. The findings of Çakın [34] are also aligned with the results of this research. This study also found that top management is curious about the application of the decentralization phenomenon. The tools discovered by Rondinelli, Nellis [49] are fundamental for efficient deployment resources. The findings of this study are diverse and purely support the decentralization without affecting the control of the owner on the organizational process; they are meant to empower people such that they feel ownership in their organization by ensuring their participation in decision making through the cascading approach of management by objective (MBO). The participants, at large, recommended a down-streaming of power, which enhances this sense of responsibility. However, this study reveals that this practice is more appropriate for medium and large organizations rather than small enterprises. The MICMAC analysis of this study asserts that decentralization is a linking variable that is associated with other variables of the study, such as knowledge management and emerging management practices. The ISM model of the study depicts that decentralization is influenced by KM practices and emerging management practices.

5. Conclusions

In conclusion, the ISM framework indicates that emerging management practices are the foundation for all other management practices in the renewable energy sector. Additionally, these are considered a driving factor that leads other business functions, which is concluded from the MICMAC analysis. Knowledge management and decentralization are considered indispensable tools of emerging management practices for the growth of the energy sector. Additionally, decentralization should also be considered important to increase the knowledge pool that eventually contributes to new ideas and their implementation. Furthermore, it is asserted that handling a large number of employees is mainly possible through decentralization practices, especially in the case of the energy sector. The energy sector is struggling with low financial resources that can be enriched through employer and employee coordination; by employing all these factors after consolidating them in the energy sector, the sector can grow exponentially in the long run.

6. Implications

The study is evocative in numerous ways after Covid-19, particularly for renewable energy companies. The duration of the pandemic provided many triggers for transforming management systems to deal with uncertain situations that may evolve in the future, and it is advocated that the application of emerging management practices has the potential to increase organizational management capacity in a turbulent and dynamic environment. Therefore, this study suggests establishing central response mechanisms supervised by resilience leadership who believe in innovative management practices, and applying them according to the contextual formation. The main objective of the study was to explore emerging management practices that can help energy organizations work efficiently during the pandemic and eventually after the pandemic situation. Mainly, the implications are segregated into two parts: (1) theoretical implications and (2) practical implications.

6.1. Theoretical Implications

There is a dearth of literature on emerging management practices and it is evolving over time. The importance of the current and updated literature during the crisis is increasing. The scarcity of literature mainly in the context of developing countries on emerging management practices is noted. Hence, this study is an important part of the literature that will help future researchers and academicians to describe and utilize the concepts for a better understanding of the phenomena. Additionally, the available literature was disjointed and confusing concerning understanding the concept of emerging management practices for renewable energy companies. Hence, this study has systematically gathered the literature and added current and contextual knowledge for a better understanding of the implications of the concept.

6.2. Practical Implications

The findings of the study are very useful for managers and policymakers to devise strategies that are helpful during emergencies and situations like Covid-19. Those strategies include developing a central response unit and flexible leadership policies. The findings of the study also help policymakers use emerging management practices as a foundation that triggers other factors, such as decentralization and knowledge management. Organizations must work on their knowledge management systems to innovate and compete during the pandemic.

7. Limitations and Future Directions

Like all research, this study also has a few limitations that need consideration for future research. The first limitation of the study is related to methodology; the qualitative research methodology has limited capacity to generalize phenomena to a larger context. Thus, future researchers can extend the extant study by using a mixed method for better exploration and generalization of the concept. Furthermore, statistical analysis should

also be used for model testing. Another limitation of the study involves the sample size: the narrow sample of the study affects the generalizability of the concept such that in the future, the sample size of the study should be increased to obtain the desired data. It would also be beneficial to gather data from all levels rather than from only top and middle levels of management.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki. The review board of the Iqra University exempted the research for ethical approval, as it was a survey-based study. Top and middle-level managers working in the renewable energy sector gave consent on the telephone for conducting a questionnaire and participants of study filled questionnaires willingly.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original data is provided by all the authors. If there are relevant research needs, the data can be obtained by sending an email to the corresponding author. Please indicate the purpose of the research and the statement of data confidentiality in the email.

Conflicts of Interest: This study has no conflict of interest.

Ethical Statement: The study is in compliance with APA (American Psychological Association) and is following all research ethical conducts. The data collection was done with their due consent and their names were kept anonymous during the study. They were informed about the purpose of the study before any kind of data collection procedure.

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Perceived Green Human Resource Management Practices and Corporate Sustainability: Multigroup Analysis and Major Industries Perspectives

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Abstract: The substantial focus on achieving corporate sustainability has necessitated the implementation of green human resource management (GHRM) practices. The purpose of this paper is to reveal the industries' perspective of the impact of GHRM practices (i.e., green recruitment and selection, green pay and rewards, and green employee involvement and green training) on corporate sustainability practices. Data were collected from 200 human resource professionals in major industrial sectors of a developing country. Partial least squares structural equation modelling was used to test the study hypotheses and multigroup analysis (MGA) between industrial sectors. The findings show a positive impact of three GHRM practices, i.e., green recruitment and selection, green pay and rewards, and green employee involvement on corporate sustainability. However, green training has no significant association with corporate sustainability, which is interesting. Furthermore, the multigroup analysis (MGA) revealed partial and significant differences among different sectors. The results provide more contextualized social, environmental, and economic implications to academics and practitioners interested in green initiatives. To date, limited research has been conducted to investigate whether GHRM practices can be an effective strategy in increasing corporate sustainability in a developing country context. Particularly, the industry's perspective on the subject matter was rather absent in the existing literature. The present study fills this gap and contributes to the existing literature by providing the industry's perspective on GHRM and corporate sustainability.

Keywords: green human resource management practices; corporate sustainability; developing country; industry perspective

1. Introduction

The notion of businesses being driven by profit-oriented activities is rapidly changing. Today, businesses and the corporate world have realized that people make the center of all activities [1]. This has changed the corporate world and gave birth to corporate sustainability that creates long-term value for consumers and employees, among others, by developing a "green" strategy [2]. This strategy focuses on the natural environment by

considering every dimension of business operations and their social, cultural, economic, and environmental impacts [3]. Corporate sustainability is a transformation of more traditional phrases that define ethical and equitable corporate practices. Though traditional expressions such as corporate social responsibility (CSR) and corporate citizenship are still common, these have already started to be replaced by corporate sustainability which is a broader and comprehensive term. Past research linked corporate sustainability to increased revenue, reduced wastes, materials, water, energy, and overall expenses. These studies also associated corporate sustainability with increased employees' productivity, reduced hiring and attrition expenses, and reduced strategic as well as operational risks [4–6]. Therefore, both practitioners and academics need to have a clear understanding of the factors affecting corporate sustainability.

Largely, firms' operations and corporate sustainability or efforts for adopting it are greatly influenced by humans [7]. Green-oriented management practices are executed entirely by humans expressing a positive attitude towards the environment and having a sense of responsibility for their actions that may have any environmental implications. Green human resource management practices (GHRM) consist of key practices such as green recruitment and selection, green training, pay and rewards, and employees' involvement. Needless to say, the role of GHRM is very significant when it comes to the development of environment-friendly norms and practices within organizations [8]. The authors argue GHRM practices play a vital role in providing the necessary ingredients for achieving corporate sustainability [9]. As such, recent literature emphasizes the significance and the potential of GHRM in achieving corporate sustainability [8].

The objective of this paper is to explore the industry's perspective on the impact of GHRM practices (i.e., green recruitment and selection, green pay and reward, and green employee involvement) on corporate sustainability practices. As there is a lack of research on the causal relationship between GHRM practices and corporate sustainability, this study is timely in filling a clear research gap. Particularly, the industry's perspective on this important subject is absent in the existing literature. The present study fills this gap and contributes to the existing literature by providing the industry's perspective on GHRM and corporate sustainability. Practically, the findings of the present study will provide practitioners to ascertain the significance of GHRM practices in achieving corporate sustainability.

Nevertheless, there is little evidence in the academic literature to confirm the relationship between GHRM practices and corporate sustainability, particularly in this emerging field of research [8,10]. Additionally, the literature also reports some recent calls to investigate the aforementioned relationship in emerging and developing countries to merge the importance of GHRM practices and corporate sustainability [8,11]. However, research further reported that the investigation of the above relationship is rare in different industries [8]. Hence, to fill this gap the current study uses the crux of the stakeholder theory in different industries such as industrial/manufacturing, information technology (IT), banking, and education. The aforesaid are the main sectors that contribute tremendously to the gross domestic product (GDP) of the sample country. Similarly, in the above sectors, the country focuses on the overall sustainability and human development as a whole.

After achieving the above research objective, the study brings several contributions to theory, method, and practices. Firstly, the study has theoretical significance to underpin the crux of stakeholder theory in the relationship between GHRM and corporate sustainability practices to satisfy the demands of multiple stakeholders. Secondly, the study contributes to the limited literature of the subject relationship particularly in developing economies context. Thirdly, the study has a methodological contribution by validating the newly developed scale of GHRM by the authors [4] in a developing country context. Finally, the study offers practical implications for the different industries of the country as the Security Exchange Commission (SEC) issued a code of corporate governance 2019 mentioning the implementation of green and sustainable workplace practices in these industries.

A brief review of the literature on GHRM and corporate sustainability is presented in the next section, which is followed by the development of research hypotheses. Next, we describe the methods employed in the present study. We then describe both the analysis and results, followed by a detailed explanation of the findings, including their implications for research and practice. The last section highlights the limitations of this research and provides several recommendations for future studies.

2. Literature Review

2.1. Theoretical Framework and Hypotheses Development

The stakeholder theory posits that the managers' core responsibility is not only to take care of the shareholders only, but they are also responsible to be impactful for general "stakeholders" [12]. The stakeholder of an organization is someone who has any direct or indirect stake in its business. In other words, anyone who affects or is affected by the operations of an organization is its stakeholder. The stakeholder thus can be either close to the business environment and has more direct stakes, e.g., employees and shareholders, or remote and having indirect stakes, e.g., communities and people/entities outside the business. Hence, the theory is selected in the study to comprehensively explain its all prepositions. Previous studies on the concept also adopted the crux of the stakeholder theory [13,14]. To achieve corporate sustainability, a company needs to look internally and externally to understand its environmental and social impacts [15]. This needs the engagement of stakeholders to know and realize impacts and concerns. A business can focus on corporate sustainability internally by training its employees and devise strategies or policies that ensure sustainability. As a company looks externally, stakeholders include customers, suppliers, community, and non-government organizations, etc. In this case, the organization is expected to deal with the diverse expectations of a long-range of stakeholders. In other words, stakeholders' involvement and engagement (both internal to organization and external to the organization) is critical for corporate sustainability. By applying the concept of sustainability and GHRM, the organization meets the demands of multiple stakeholders. Similarly, the crux of the stakeholder theory also applies in the different industries such as industrial/manufacturing, banking, and education and information technology (IT) [16–18]. Moreover, these stakeholders' demands may vary in these different industries; however, the importance would still be vital [19]. Corporate Sustainability and GHRM are two interrelated subjects, as both strive to serve the interest of internal and external stakeholders, thereby focusing on the impact of the social, environmental, and economic performance of the organization.

2.2. Corporate Sustainability

In 1980, the Worlds Commission on Environment and Development (WCED) came up with the terminology of "sustainable development" and it linked sustainability to environmental integrity and social justice [20]. This report devised the definition of sustainable development as "sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [20]. The definition also links sustainability with the corporate world and economic prosperity. The definition was acknowledged by international leaders who attended the Earth Summit in 1992 held in Rio de Janeiro [21]. Along with the environmental and economic challenges, organizations are demanded to improve human and social welfare and simultaneously to decrease the organizations' ecological effects, while also safeguarding the efficacious and efficient attainment of organizational goals [22,23]. Building on the literature around management and strategy formulation, numerous definitions of sustainability have evolved in the context of organizations. These definitions diverge on three different levels: (1) the degree to which corporate sustainability could be classified either largely as an ecological concern [24] or (2) as an organization's social responsibility [7], or perhaps (3) expand and contribute to the theory to integrate organizational interest around the natural and the social environment with corporate economic activities [25].

The terminology of "corporate sustainability" is also used by various scholars to define the integration of organizational concerns of social, environmental, and/or economic nature embedded in the culture of the organizations, their decision-making process, the strategy formulation, and implementation as well as operations [25]. External factors, such as environmental regulations, government standards, and laws, or demands/expectations from pressure groups, e.g., customers and community, etc., are considered the primary driving forces behind the adoption process. While the factors within the organization are mostly considered as a "black-box" [26], this attitude leaves a huge vacuum that is not taken into consideration. For Example, many recent research studies have pointed out the "pressures from within the organization" for the adoption of practices that promote and ensure sustainability [27]. Furthermore, these studies also identify factors internal to organizations, for example, support of the top management, management of the human resources, training(s) on pro-environment issues, empowerment of employees, teamwork and reward systems, etc., as important facets for attaining corporate sustainability [28]. Yet, some researchers believe that more wide-ranging changes in employees' values and relevant norms are essential ingredients for accomplishing corporate sustainability in its true sense [7]. Together, these two stances propose that corporate sustainability is a multi-layered concept, and the organization may consider its operationalization which would require change and adaptation from the organizations on several levels.

For an organization to be sustainable, GHRM certainly matters for various reasons; however, primarily it matters because stakeholders expect organizations to use resources wisely and responsibly. In other words, organizations are expected to protect the environment, minimize the usage, or more specifically the wastage of air, water, energy, minerals, and other materials in manufacturing the goods we consume. Moreover, organizations are expected to recycle and use these goods again to the possible extent instead to rely on nature to restore or renew these for us. Organizations are expected to preserve nature's beauty and tranquility and mitigate any or all toxicity that could potentially harm people in the workplace as well as communities [29]. Following the sustainable development principles, the social, economic as well as environmental objectives are mutually dependent and reinforcing [30]. Hence, the companies' developmental strategies should take into account a balance among the economic, environmental, and social dimensions of their economic tasks or undertakings. This implies that the agreed economic solutions be considerate of social responsibility, environmental friendliness, and economic value [31].

2.3. GHRM and Corporate Sustainability

GHRM is a derived term evolved from green management philosophy, policies, and practices followed by firms for environmental management (EM) [27]. It is defined as the portion of human resource management which is focused on efforts to transform organizational employees into green employees with a vision to attain organizational sustainability goals (for example, increasing business opportunities, employees' motivation, the public image of the brand and/or business and compliance with environment-friendly policies and laws and reducing labor turnover and utility costs, and creating competitive advantage) and also make a significant contribution to the environment [32]. GHRM is also defined as a system that uses HRM policies to promote the use of resources within business organizations to promote environmental sustainability [33,34]. Reading through the theory related to the definition of GHRM and the movement behind it, three key principles guide the philosophy of GHRM, such as the principles of environmentalism, sustainability, and social justice.

GHRM promotes the sustainable use of all types of resources, which supports the cause of environmental sustainability in general, and enhances employees' awareness and commitments towards the challenges of environmental management in particular [5,35]. Additionally, the development of GHRM includes improving the social (balance between work and life) and economic (i.e., sustainable profits) related matters. GHRM supports the classic understanding of the concept of the "triple bottom line"; that is to say, GHRM

involves practices alongside the three key dimensions of sustainability, i.e., environment, social, and economic balance [32,36,37] to bring benefits to the organization in the long run [30,38]. To expand the understanding of the subject matter, developing GHRM measures is a work that is in progress. For example, some of the presented measures lay down ecologically relevant HRM policies and practices that are differentiated as the functional (job description and analysis, recruitment, selection, training, performance appraisal, and reward system) and competitive dimensions (team, culture, and organizational learning) of GHRM [36].

GHRM has been measured with four constructs, i.e., employee life cycle, rewards, education and training, and employee empowerment [37]. Later, it was measured using four other practices including green recruitment, green training, green pay and compensation, and green employees' involvement [39]. Recently, GHRM is also measured with the five-factor model including environmental training, investment in people, creation of work-life balance and family-friendly employment, improved employee health and safety, and employee participation in decision-making processes [40]. Building on the data collected from China, Malaysia, and Pakistan, three fairly new and broad GHRM measures are proposed [2,4,29]. However, all these efforts were mainly focused on environmental concerns from the perspective of the organization. Nonetheless, little work has been carried out in this regard so far to conceptualize GHRM as a possible roadmap for achieving corporate sustainability. Similarly, few previous studies that investigated the impact of GHRM on corporate sustainability have documented a positive relationship in the context of Palestinian healthcare organizations [41] and Malaysian manufacturing firms [8]. Likewise, past research hints at the key role of GHRM in achieving corporate sustainability in the context of developing countries [18,42,43].

To help us understand in what way organizations can convert HRM practices into "green" initiatives that are more likely going to support corporate sustainability, the different dimensions or practices of GHRM are discussed below.

2.3.1. Green Involvement (GI)

Green involvement refers to the involvement of organizational employees in green-activities. This involvement of employees in green activities stimulates and inspires them to support the prevention of pollution and excessive waste [41,42]. A review of numerous studies establishes a point in favor of green involvement (GI) of employees, according to which GI is a crucial factor in improving the performance of organizations (For example, reducing waste, pollution, and making full use of resources in a workplace) [36,44,45]. As part of adopting green practices, organizations have to encourage and inspire their workforce to become involved by initiating green and eco-friendly ideas. This could be achieved by empowering workers [33,36]. For this drive, the human resource department can work on highlighting the importance and requirement of creating a participative work environment for strategic level managers: an environment where employees feel confident and keep no fear in disagreeing with top managements' decisions or negotiating with them. In other words, an environment where employees can propose or offer diverse ideas to deal with important organizational issues [40]. However, the importance of empowering employees and their participation originates from the fact that employees like to be autonomous when making decisions regarding environmental problems and other issues associated with sustainability that may emerge in the implementation of corporate sustainability and its various initiatives [46,47]. To achieve this, employees must be involved in the formulation of environmental strategies, which should then enable them to develop and expand on the required knowledge for green products and services. The insight developed from the literature regarding employees' involvement could be concluded as enabling employees to give suggestions and to be involved in the problem-solving responsibilities which are the main pillars for ensuring and encouraging their participation in green initiatives. Based on this, the following hypothesis has been formulated:

H1: *Green Involvement is perceived to have a positive impact on corporate sustainability practices.*

2.3.2. Green Pay and Reward (GPR)

The strategic approach of rewards management (RM) suggests green pay and reward (GPR) is "a system of financial and non-financial rewards" that is aimed to achieve the goal of attracting, retaining, and finally motivating employees who are best suited for contributing towards green goals of the organization [36]. Accomplishing the objectives of greening the organization can be improved by rewarding employees for their commitment to exhibit and promote green behaviors as well as sustainable practices [36]. In this context, corporate sustainability could benefit from reward and compensation systems if it concentrates on limiting or eliminating undesirable behaviors and encourage green behavior [5]. To reach this goal, reward systems should be designed to reflect the commitment of strategic-level managers towards greening [46,47]. This strategic level commitment will inspire workers too using becoming more environmentally responsible and more involved in green initiatives [36,48,49]. A study links the success of rewards programs aimed at motivating employees to exhibiting and promoting green behaviors by joining rewards with greening [44]. This leads to the formulation of the following hypothesis:

H2: *GPR is perceived to have a positive impact on corporate sustainability practices.*

2.3.3. Green Recruitment and Selection (GRS)

GRS is the process of attracting candidates who are committed or have a high potential to contribute to environmental issues linked with the organization [4]. GHRM practices consider green recruitment and selection an important component that helps identify green employees who exhibit green inclinations and helps develop a green culture [42]. Based on the studies carried out previously, e.g., [4,42], briefly, there could be three aspects of GRS, i.e., "green awareness of candidates, green employer branding, and green criteria to attract candidates". Green awareness of candidates is the first and most important aspect of GRS [4,42]. Firstly, it is the green awareness of employees (candidates) that enables an organization to achieve its environmental goals and goals linked to cost effectiveness, etc. Therefore, to ensure that candidates are positive towards organizational strategic green goals, the firms should run a series of tests that enable them to choose the best. Secondly, the green employer branding generally refers to the development of a green reputation of the company through better environmental management that is formed via GHRM practices [42]. Thirdly, there have to be green criteria for an employee to be selected and evaluated [45]. GRS make sure that new employees must not only understand the established green culture of the organization but also share its environmental values [50] through continuous enhancement of environmental knowledge of recruits and ingraining of values and beliefs [42,45]. Some studies suggest that recruitment communications should contain environmental criteria [32]. However, the author recommends several preventive and institutive actions that organizations can embrace to enrich GHRM through GRS processes [48]. Firstly, job descriptions should consist of features that emphasize the role of environmental reporting. Secondly, an induction program for recruits must ensure the availability of information around environmental sustainability policies of the organization, values, and green goals.

Finally, interviews have to be designed in a way to assess the potential agreeableness and fitness of the candidates with the greening programs of organizations. The emphasis laid on the GRS process indicates that during the interview process candidates must be asked more environment-related questions. Additionally, the authors described that organizations can expand their determinations to safeguard the environment using combining environmental tasks and responsibilities of every employees' job description [49,51]. It can also be carried out by designing new jobs or positions to focus exclusively on corporate sustainability aspects of the organizations [49]. Based on this, the following hypothesis has been articulated.

H3: *GRS is perceived to have a positive impact on corporate sustainability practices.*

2.3.4. Green Training (GT)

Green training is a combination of coordinated activities that encourage and inspire employees to acquire skills around the protection of the environment and give consideration to environmental issues that play a key role in achieving environmental objectives [49,52]. Training helps improve employees' awareness, knowledge, and skills relevant to environmental activities [52]. Researchers suggest that the provision of green training must be ensured along with educational programs to all employees of the firm, and these training(s) and educational programs must not be restricted to the organizational departments of the environment [49]. The authors advocate and recommend various green training and development practices, such as employees' training for ensuring green analysis of workspace, energy efficiency, waste and recycling management, as well as the development of personal capacities on green concepts and strategies [6,49,50,52]. Therefore, it is important in organizational training and development plans to include programs, seminars, and sessions that may enable workforces to develop and acquire knowledge in green skills [53]. Additionally, the authors describe that firms should make those opportunities available which allows employees' engagement in environmental problem-solving missions [54]. To accomplish these goals, job rotation philosophies must be used as a crucial component of training and career development strategies [53]. Considering the green aspects embedded in the training process, the following hypothesis has been framed. Figure 1 represents the hypotheses development of the study.

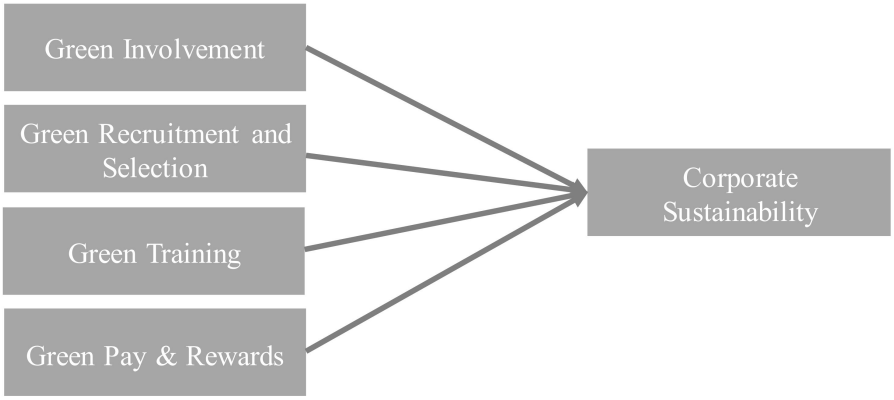

Figure 1. Conceptual Framework.

H4: *GT is perceived to have a positive impact on corporate sustainability practices.*

The above hypotheses are explained in Figure 1 as follows.

3. Research Design

3.1. Instrument

GHRM Practices: The GHRM practices were measured using a 15-item scale from Tang et al. (2018). The scale covers green involvement (GI), green recruitment and selection (GRS), green pay and reward (GPR), and green training (GT). The minimum and maximum reliability of the GHRM scale was recorded from 0.83 to 0.87. For the corporate sustainability construct, we adapted a scale from Tom (2015). The items include questions covering knowledge of sustainability of the respondents, followed by the focus of integrated dimensions such as social, economic, and ecological dimensions. The sample item includes "we know enough about corporate sustainability". The reliability score of the corporate sustainability construct was 0.862 [55].

3.2. Sample Size and Data Collection

G*Power software was employed to calculate the minimum sample size with a significant level of 0.05 and the power of 0.95. A priori power analysis using a medium

effect size suggested a sample size of 138. Thus, the present sample size (N = 200) for this research was deemed appropriate. However, due to the potential of missing values, non-response rate, and outliers, we distributed 250 questionnaires (Appendix A) among the HR professional working in different industrial sectors of Pakistan such as manufacturing, banking, education, and information technology (IT). These industries are the main contributors to the economy. Before the data collection, the respondents were informed regarding the ethical considerations, the study objectives and ensured the confidentiality of the information. After the due consent for the questionnaires filing, the questionnaires were distributed using a self-administered approach. The self-administered data collection approach carries the advantage of a high response rate of up to 90% [56]. Hence, of the distributed questionnaires, respondents returned the filled questionnaire with a response rate of 80% and hence was acceptable [56]. However, seven incomplete questionnaires were excluded. A total of 200 samples were submitted for final data analysis. Data were collected between September 2019 and January 2020.

3.3. Demographic Profile of Respondents

The respondents were from various professional levels, experiences, educational backgrounds, and diverse sectors.

Since the purpose of the study was to understand the impact of GHRM on corporate sustainability, the respondents must be individuals who are currently holding a position in the company's HR department or equivalent to represent his/her organization. An invitation letter including a questionnaire along with a consent form that clearly stated the purpose of the study, and its possible logical conclusion was provided to the participants as exhibited in Table 1. The Table reports the details of the participants of the survey. Among 200 participants, 78.57% represented males, while 21.43% accounted for females. The ratio of males is higher than females as females of the sample country are less job-oriented as well as less participative in the survey [57,58]. Regarding age, it is found that we have a mix of ages. The majority of the participants (55%) were holding a Master's degree, followed by Bachelor's degree holders (37%). The average experience and the total were collected from almost every managerial level. Twenty-seven percent of participants belonged to the industrial sector, the remaining (73%) having an association with banking (23%), education (24%), and information technology sectors (24%).

Table 1. Demographics of respondents (N = 200).

Variable	Categories	Percentage
Gender	Male	78.57
	Female	21.43
Age	20 or fewer years old	14.28
	21–30 years old	41.18
	31–40 years old	31.93
	41–50 years old	12.61
Education	Bachelor	37.39
	Master's Degree	55.04
	MPhil	5.88
	Ph.D. and Above	1.68
Experience	1–5 years	14.71
	6–10 years	27.73
	11–15 years	22.69
	16–20 years	18.49
	20 or above years	16.39
Position	Entry Level	21.43
	Intermediate Level/Experience Level	40.76
	Line Management	11.34
	Middle Management	10.50
	Senior Management	15.97
Sectors	Industrial	27.31
	Banking	23.11
	Education—Universities	24.79
	Information Technology (IT)	24.79

4. Data Analysis and Results

Partial Least Squares Structural Equation Modelling (PLS-SEM) using SmartPLS 3.0 was used for data analysis [59]. PLS-SEM is considered a good choice for HRM models when the goal of the study is to explore key predictors of the outcome variables. Measurement model (internal consistency reliability, convergent validity, and discriminant validity), structural model (R-square (R^2), path coefficient, f^2, and Q^2), and multigroup analysis (significantly differs between groups) were performed [60,61].

Table 2 summarizes the results of convergent validity and internal consistency reliability. All indicators and constructs are found to have met the reflective measurement criteria. Specifically, the outer loadings (λ) are all above 0.651, demonstrating that indicator reliability is achieved [59]. Moreover, the average variance extracted (AVE) values are all more than 0.50, denoting that convergent validity is also achieved [59]. Furthermore, composite reliability (CR) values are 0.822 or higher, which are clearly above the required minimum level of 0.70 and thus have secure internal consistency [59]. In other words, the test results show the measurement criteria of the model are being achieved.

Table 2. Measurement model.

	Loadings	**CR**	**AVE**
Corporate Sustainability (CS)	-	0.840	0.516
CS2	0.744	-	-
CS3	0.745	-	-
CS4	0.760	-	-
CS5	0.540	-	-
CS7	0.775	-	-
Green Involvement (GI)	-	0.846	0.524
GI1	0.687	-	-
GI2	0.717	-	-
GI4	0.792	-	-
GI5	0.695	-	-
GI6	0.722	-	-
Green Pay and Reward (GPR)	-	0.830	0.621
GPR1	0.799	-	-
GPR2	0.848	-	-
GPR3	0.709	-	-
Green Recruitment and Selection (GRS)	-	0.822	0.615
GRS1	0.855	-	-
GRS2	0.901	-	-
GRS3	0.651	-	-
Green Training (GT)	-	0.827	0.615
GT1	0.803	-	-
GT2	0.740	-	-
GT3	0.808	-	-

Discriminant validity is the degree to which a construct is unique from its counterparts [62]. The criterion was used to determine the discriminant validity proposed by the authors [63]. The values in the diagonal must be larger than all other values in the corresponding rows and columns [62]. As shown in Table 3, all the diagonal values are higher than others, thereby confirming the discriminant validity.

Table 3. Fornell–Larcker criterion.

	(1)	(2)	(3)	(4)	(5)
Corporate Sustainability (1)	**0.718**	-	-	-	-
Green Involvement (2)	0.687	**0.724**	-	-	-
Green Pay and Reward (3)	0.679	0.663	**0.788**	-	-
Green Recruitment and Selection (4)	0.650	0.666	0.672	**0.784**	-
Green Training (5)	0.631	0.718	0.667	0.694	**0.784**

The assessment of the structural model includes R^2, effect size (f^2), multicollinearity (VIF), model fit, coefficients, p-values, and t-values [62]. Tables 3 and 4 summarize the results of the structural model. Before moving into this step, we first test the collinearity of the structural model. Collinearity is measured using the Variance Inflation Factor (VIF).

Table 4. Structural model results.

Construct	Adj. RSqr	f^2	Q^2	VIF	SRMR	NFI	rms Theta
Green Involvement	-	0.089	0.023	2.383	-	-	-
Green Pay and Reward	-	0.039	0.011	2.264	-	-	-
Green Recruitment and Selection	-	0.082	0.026	2.597	-	-	-
Green Training	-	0.005	0.000	2.756	-	-	-
Corporate Sustainability	0.578	-	-	-	0.073	0.736	0.198

Table 4 reports that all VIF values are below the threshold of 5, suggesting that there is no such issue of collinearity among the constructs [62]. The adjusted R^2 measures the predictive power of the model, and this shows the amount of variance in the endogenous variable that can be explained by the exogenous variables. The adjusted R^2 (0.578) indicates that all GHRM practices combined to contribute more than 57% to corporate sustainability.

Table 4 also reports the effect size using f^2 of the model. The values range from 0.005 to 0.089, which fall in the small category of effect size. The Q^2 value indicates the predictive relevance values generated of variables. All the values of Q^2 are >0, which means that the model has predictive relevance. The values of the goodness of fit that were generated through the standardized root mean squared residual (SRMR) are equal to 0.073 < 0.080; the normed fit index (NFI) 0.736 is close to 1; and the rms Theta are close to <0.20, which means that our model fits the empirical data.

The statistical values furnished in Table 5 indicate a positive significant relationship ($\beta = 0.308$, t-value = 3.945, $p < 0.01$) between green involvement and corporate sustainability which supports our first hypothesis (H1) of the study. The findings are in line with the previous authors who found that green involvement is a crucial factor in improving sustainability performance such as reducing waste, pollution, and making full use of resources in a workplace [42,64].

Table 5. Hypotheses testing.

Structural Paths	Std Beta	Std Error	*t*-Value	*p*-Values	95% CI LL	95% CI UL	Decision
GI > CS	0.308	0.078	3.945	0.000 **	0.165	0.480	H1 Supported
GPR > CS	0.296	0.069	4.295	0.000 **	0.151	0.427	H2 Supported
GRS > CS	0.199	0.069	2.874	0.004 *	0.065	0.339	H3 Supported
GT > CS	0.068	0.100	0.673	0.501	–0.135	0.273	H4 Not Supported

Note: **, *: statistically significant at the 1 percent and 5 percent levels, respectively.

Similarly, the numerical values provided a positive significant relationship (β = 0.296, *t*-value = 4.295, $p < 0.01$) between green pay and reward and corporate sustainability which supports our second hypothesis (H2). Our results are according to the postulations of previous studies that stated that green performance rewards both financial and non-financial motivate the employees to participate and improve the corporate sustainability of the organization [6,65].

Likewise, there is a positive significant relationship (β = 0.199, *t*-value = 2.874, $p < 0.01$) between green recruitment and selection and corporate sustainability which clearly supports our hypothesis (H3) of the study. These results support previous studies that recorded that green recruitment and selection is an important component that helps identify green employees who exhibit green inclinations and helps develop corporate sustainability culture within the organization [45,49]. Lastly, the relationship between green training and corporate sustainability is not supported as the *p*-value is >0.05.

By employing PLS structural model technique, the study performed multigroup analysis. "PLS multigroup analysis is used to determine if the PLS model significantly differs between groups" [60]. The author further explained multigroup analysis by using independent samples *t*-tests to compare paths between groups [66–68]. The multigroup analysis is "parametric" because significance testing requires the assumption of multivariate normal distributions, unlike traditional PLS. As the study consists of different groups of industries, it is important to evaluate the difference between these groups.

Table 6 reported the multigroup analysis for four sectors, namely, industrial, banking, information technology (IT), and education sectors. The study assumes the industrial sector as the dirtiest industry, and hence selected it as a base industry. According to the statistics of parametric and Welch–Satterthwaite tests, there is a significant difference between green recruitment and selection and corporate sustainability of industrial and banking sectors (showing in bold figures). The results explain that the banking sector performs better in green recruitment and selection and corporate sustainability practices than the industrial sector. However, there is no significant difference between the two industries for the rest of the variables or their association. On the contrary, the green involvement and corporate sustainability path are significant between the industrial and IT sectors. Surprisingly, the industrial sector performs better than the IT sector in the aforementioned practices. Lastly, the study found significant differences in the association of green recruitment and selection with corporate sustainability in the industrial and education sectors. Thus, it is concluded that the education sector performs better than the industrial sector for the association of green recruitment and selection with corporate sustainability. However, there is no significant difference between the two industries for the rest of the variables or their association.

Table 6. Multigroup analysis (MGA) between industries.

Industrial - Banking	**Path Coefficients-Diff (Industrial - Banking)**	***p*-Value Original 1-Tailed (Industrial vs. Banking)**	***p*-Value New (Industrial vs. Banking)**	***p*-Value (Parametric Test)**	***p*-Value (Welch–Satterthwaite Test)**
GI > CS	0.112	0.344	0.688	0.625	0.667
GPR > CS	0.025	0.451	0.903	0.897	0.907
GRS > CS	**–0.627**	**0.968**	**0.064**	**0.010**	**0.047**
GT > CS	0.398	0.119	0.238	0.193	0.239
Industrial - IT	Path Coefficients-diff (Industrial vs. Banking)	*p*-Value original 1-tailed (Industrial vs. Banking)	*p*-Value new (Industrial vs. Banking)	*p*-Value (Parametric Test)	*p*-Value (Welch–Satterthwaite Test)
GI > CS	**0.535**	**0.002**	**0.004**	**0.004**	**0.006**
GPR > CS	0.109	0.285	0.57	0.574	0.611
GRS > CS	–0.232	0.879	0.243	0.2	0.253
GT > CS	–0.435	0.957	0.087	0.073	0.071
Industrial - Education	Path Coefficients-diff (Industrial vs. Banking)	*p*-Value original 1-tailed (Industrial vs Banking)	*p*-Value new (Industrial vs Banking)	*p*-Value (Parametric Test)	*p*-Value (Welch-Satterthwaite Test)
GI > CS	0.067	0.338	0.675	0.677	0.671
GPR > CS	0.144	0.139	0.278	0.29	0.285
GRS > CS	**–0.342**	**0.995**	**0.010**	**0.006**	**0.006**
GT > CS	0.024	0.464	0.929	0.906	0.901

5. Discussion and Conclusions

This study aimed to investigate the industry's perspective on the impact of GHRM practices (i.e., green recruitment and selection, green training, green pay and rewards, and green employee involvement) on corporate sustainability practices. It was interesting to see how the industry perceives GHRM practices as important factors for corporate sustainability. The findings indicate that human resource is an important stakeholder if managed well, which assists organizations in attaining corporate sustainability. Green awareness of the employee (candidate) enables an organization to achieve its sustainability and organizational strategic green goals. In the same way, green employer branding generally develops the green reputation of the company through better environmental management that is formed via GHRM practices [42], specifically during the recruitment and selection process. The results further documented that green involvement and recruitment and selection vary among the industries particularly among industrial, banking, and education sectors. For instance, the association of green recruitment and selection with corporate sustainability in the banking sector is better than in the industrial sector. Likewise, green involvement has a significant relationship with corporate sustainability in both the industrial and IT sectors, where the performance of the former is better than the latter. Besides, the education sector has better statistics than the industrial sector for the impact of green recruitment and selection on corporate sustainability.

Unexpectedly, unlike past findings, the results of the present study show that the respondents of the study do not perceive green training as the predictor of corporate sustainability. One of the reasons for such findings is that in fast-paced business activities employees are being pushed to focus more and more on core activities of daily operations, thus other activities such as "training" are probably going to be assumed less important. The findings also show a strong and significant nexus of green involvement with corporate sustainability. This finding is consistent with the prior literature reporting that green involvement is a vital element in improving sustainability performance, such as reducing waste, pollution, and making full and efficient use of resources at the workplace [42,64].

Likewise, the results of the present study also confirm the significant positive relationship between green pay and reward and corporate sustainability. This result endorses the claims of previous literature that both financial and non-financial rewards motivate employees to participate and improve the corporate sustainability of the organization [6,65].

The finding of this study offers several implications for theory and practice. First, the study contributes to the limited literature of GHRM practices and corporate sustainability by increasing the understanding of their nexus. Second, there is a lack of literature on GHRM practices and corporate sustainability, particularly in developing and emerging economies. Hence, the study partially validated a newly developed GHRM scale by the authors [4] in the developing country context. Third, the study underpins the crux of stakeholder theory for the subject relationship and hence has practical implications for the CEOs and HR managers to implement GHRM and integrate corporate sustainability within the organization for the satisfaction of multiple stakeholders in developing countries. From a practical perspective, the study sheds light on how an organization implements GHRM initiatives by involving its employees in green practices. Organizations should recruit and select their employees through the green process, train them in, and design their pay and reward system sustainably. The findings of the study help organizations by addressing the broad agenda of sustainable productions by adopting GHRM and corporate sustainability practices particularly in industrial and IT sectors. Similarly, the findings bring practical implications for the banking sector as the regulator issued a policy towards the implementation of green banking practices. Likewise, the findings also helpful to inform the education sector, particularly the universities, on the adoption of the broad agenda of education for sustainable development (ESD).

This study has a few limitations that may be addressed in future studies. Firstly, as in the current study the perceptions of the industrial respondents are captured, in future studies the model should be replicated on a general sample such as business graduates, academics, and other practitioners related to the fields. Similarly, the new scale developed by the author [2] should also be tested in the sample country context. Secondly, in the future, the studies should be directed towards qualitative aspects of the GHRM practices, and their role in the implementation of corporate sustainability. Thirdly, the available theory used for this study also paves a path for considering organizational culture and strategic orientation variables for any future studies. This would be carried out by utilizing the moderating and mediating models in the relationship between GHRM and corporate sustainability. Last but not least, the studies in future directions should consider the multigroup analysis and longitudinal nature, particularly secondary data analysis.

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Appendix A

Questionnaire of the Study

Corporate Sustainability

1. We know enough about corporate sustainability.
2. Organizations, where operations are based on sustainable growth, social responsibility, and environmental protection, are sustainable organizations.
3. Sustainable organizations would consider sustainability as one of the essential components of the corporate culture.
4. Sustainable organizations exploit environmental challenges and legislation to their advantage by developing new greener products.
5. Ecological regulations add more restrictions on firms.
6. Due to ecological constraints, it is okay to think of relocating production to other countries, where ecological requirements are lower.
7. Sustainability has to be taken as an important route for the long-term development of the enterprise.

Green Recruitment and Selection

1. We attract green job candidates who use green criteria to select organizations.
2. We use green employer branding to attract green employees.
3. Our firm recruits employees who have green awareness.

Green Involvement

1. Green organizations have a responsibility to provide a clear developmental vision for the guidance of the employees' actions in environmental management.
2. The green firm shall have a mutual learning climate among employees for green behavior and awareness.
3. In green organizations, there should be several formal or informal communication channels to spread green culture within the organization.
4. Green organizations are those that involve employees in quality improvement and problem-solving on green issues.
5. Green organizations involve their employees by offering practices to participate in environment management (such as newsletters, suggestion schemes, problem-solving groups, low-carbon champions, and green action teams, etc.).
6. Those organizations that emphasize a culture of environmental protection are green.

Green Pay and Reward

1. The green organization will make available green benefits to its employees such as combine transportation and travel to support green efforts.
2. Provision of financial or tax incentives to employees is an essential part of the 'Pay and Reward' system in a green organization (e.g., bicycle loans, use of less polluting cars)
3. Recognition-based rewards in environment management for staff (e.g., public recognition, awards, paid vacations, time off, gift certificates) are given due importance in the green organization.

Green Training

1. Organizations with GHRM must develop training programs in environmental management to increase environmental awareness, skills, and expertise of employees.
2. Organizations with GHRM should consider integrating training to create the emotional involvement of employees in environment management.
3. Organizations with GHRM will have a defined green knowledge management system (link environmental education and knowledge to behaviors to develop preventative solutions).

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sustainability

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Article

Alignment of Islamic Banking Sustainability Indicators with Sustainable Development Goals: Policy Recommendations for Addressing the COVID-19 Pandemic

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Abstract: This study aims to establish the link of key Islamic banking sustainability indicators with the United Nations' Sustainable Development Goals (UN SDGs) as a policy recommendation for sustainable development and to mitigate the distressing impacts of the COVID-19 pandemic on the triple bottom line (people, planet, and profit). To identify the key Islamic banking sustainability indicators, the authors selected the most cited sustainability measurement indexes in Islamic banking. Initially, the indexes were divided into 10 broader themes, and then the key Islamic banking sustainability indicators were shortlisted from each theme based on their high-frequency distribution. The shortlisted sustainability indicators were then ratified to be in line with Islamic philosophy based on "Maqasid al-Shariah" (objectives of Shariah) and were subsequently grouped into the three dimensions of economic, environmental, and social sustainability based on the axial coding method. Finally, the categorized sustainability indicators were aligned with the relevant UN SDGs through the axial coding method for policy formulation, and respectively 12 propositions were developed for policy formulation. This study labeled the methodological process of this study as the ECA method (exploration, categorization, alignment). The new ECA method offers a reverse extension in the "SDG compass" developed by the Global Reporting Initiative (GRI) for aligning business policies with the UN SDGs. The process of aligning Islamic banking sustainability indicators with the UN SDGs will provide a roadmap to recovery from the COVID-19 pandemic in terms of economic, environmental, and social issues. Due to the diversity of the UN SDG framework, it covers multiples aspects for sustainable development. Therefore, considering the UN SDGs in terms of various banking instruments will mitigate the multiple distressing impacts of COVID-19 on the triple bottom line (people, planet, and profit), it will also promote a sustainable development agenda.

Keywords: the ECA method; UN SDGs; COVID-19 coronavirus; Islamic banking; Maqasid al-Shariah; sustainability practices; sustainability indicators; SDG governance

1. Introduction

COVID-19 started as a health crisis but swiftly turned into an economic crisis and is continuing to evolve into a humanitarian crisis. COVID-19 and its various impacts are

still ongoing and its full-scale consequences on the triple bottom line (e.g., people, planet, and profit) are still unknown [1,2]. According to an April 2020 International Monetary Fund (IMF) report titled "World Economic Outlook" the global economy is projected to contract by 3% in 2020 with an accumulative loss of around USD 9 trillion, which is worse than the financial crisis of 2008. According to the United Nations (UN) projections, the world is facing the worst economic recession since the Great Depression. In line with the humanitarian crisis, according to Nicola, et al. [3], the COVID-19 has affected more than one billion children in schools, which accounts for about 67% of total enrolled students globally. There are fears that due to the current turmoil students from underdeveloped or developing countries may completely lose their education. This can result in more child-labor cases. The effects of COVID-19 are incredibly diverse, i.e., from poverty to education, to health, to economic growth, etc. Therefore, one framework that can bring all these diverse aspects under one umbrella is the United Nations Sustainable Development Goals (UN SDGs). The UN SDGs have 17 goals with 169 targets and 232 indicators set to resolve diverse global problems. The framework provides an opportunity to the world for sustainable development through ensuring and considering the UN SDGs in the recovery plans.

The financial shutdown resulting from the COVID-19 pandemic globally has had a significant impact on various business sectors [3,4]. Business sectors have seen the significant scale-down of production and employment due to the reduced demand and cash flow constraints [5]. The Islamic banking industry is not isolated, it also was affected by the pandemic [6,7]. However, its measurable impact would unfold steadily. Before the pandemic, the demand for Islamic banking financing, deposits, and assets grew gradually. According to the Islamic Financial Services Industry Stability Report 2019, the cumulative annual growth rate (CAGR) of Islamic banking for the period of 2013–2018 increased by 7.1% for Islamic finance, 7.4% for deposits, and 7.2% for Islamic banking assets. Now, in the context of the imminent global recession, the Islamic banking industry, along with the rest of the world, is looking forward to a long path of recovery and confronting new business challenges.

Extant literature suggests that Islamic banks showed a paucity of compliance towards adopting the UN SDGs in terms of sustainable business practices [8–21]. This lack of compliance towards the UN SDGs may increase regulatory challenges and stakeholders' pressure for Islamic banks at different levels. The improvement in education has equipped multiple stakeholders for global business trends, including the positive effect of sustainable business practices on Islamic banks' financial results. A huge body of knowledge is available on the subject that indicates that sustainability practices improve financial performance in the case of Islamic banks [19,22]. In this case, the investors and depositors of Islamic banks would demand their banks to be prudently involved in sustainability practices, because they will get an economic return against it. Other stakeholders in the form of different public groups and interest groups that are advocating for the environment are also putting pressure on banks to comply with the environmentally friendly activities and practices. The lack of compliance is also increasing regulatory challenges for the Islamic banking industry in different countries. For instance, Bank Negara Malaysia (BNM), through its policy paper called "Value-Based Intermediation" (VBI), nudged Islamic banks to commence sustainable business practices [23]. Therefore, to pacify multiple stakeholders and regulators, the adoption of sustainable business practices has almost become mandatory for Islamic banks.

The COVID-19 outbreak not only highlighted the urgency of research into a vaccine but also shifted the dynamics of Islamic banking towards new business trends such as clarity and solutions for a sustainable Islamic banking industry. Haider Syed, et al. [4] and the United Nations Development Program (UNDP) in its recent report (https://www.undp.org/content/undp/en/home/blog/2020/islamic-finance-takes-on-covid-19.html) published in April 2020 highlighted that Islamic sustainability instruments (such as zakat and Qard-e-Hassan) can help nations in preparing for, responding to, and recovering from the pandemic [24]. This provides an opportunity for Islamic banking to help various stakeholders suffering through the pandemic [25]. Against that background, this article

aims to identify the key Islamic banking sustainability indicators and align them with the SDGs. Firstly, it will unleash the potential of Islamic banking sustainability indicators to various stakeholders around the world. Secondly, it will provide policy guidelines for the stakeholders in responding to the pandemic using specific business instruments. Thirdly, and most importantly, it will help the world to recover from the pandemic in terms of economic, environmental, and social business issues. Finally, these fundamental steps will pave the way for sustainable Islamic banking in the long run. The following sections show the literature review and theoretical framework, followed by the linkage of Islamic banking sustainability indicators with the UN SDGs and the commentary. Last, this article provides a conclusion, future directions contribution, and policy guidelines.

2. Literature Review

2.1. The Concept of Islamic Banking and its Global Profile

Islamic banking refers to a banking system based on the laws of Islam known as Shariah objectives, or Maqasid al-Shariah, and guided by Islamic economics [19]. The two basic principles that distinguish Islamic banking from their conventional counterparts are sharing of profit and losses [26], and prohibition of interest [27]. Islamic banking is the main component of Islamic finance other than Sukuk (Islamic bonds), Islamic funds, and Takaful (Islamic insurance). The breakdown of global Islamic finance is shown in Figure 1 below.

Islamic Banking	72.4%
Sukuk	22.3%
Islamic Funds	4.2%
Takaful	1.1%

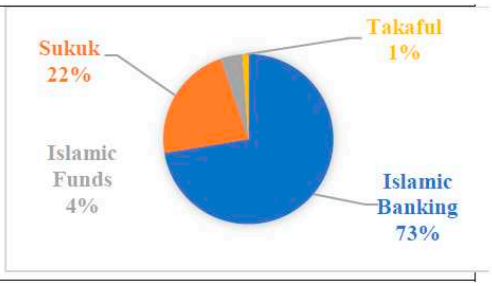

Figure 1. Breakdown of Islamic finance (year-end 2019) (Source: Islamic Financial Services Industry Stability Report 2020, p. 13).

The above Figure 1 shows the data as per the year-end 2019. The Islamic banking industry retains the major portion of the global Islamic financial market. According to the Islamic Financial Services Industry Stability Report 2019, the share of global Islamic banking assets is about USD 1.57 trillion. The subsequent Figure 2 shows the share of Islamic banking assets per country.

Figure 2 shows data as per the third quarter of 2019. The market leaders in the world of Islamic banking are Iran, Saudi Arabia, Malaysia, UAE, Kuwait and Qatar. These six countries collectively possess approximately 85 percent of the world Islamic banking assets share. The second tire Islamic banking countries as per global Islamic banking shares are Turkey, Indonesia, Bangladesh and Pakistan. While the countries with the least share in the world Islamic banking industry are Brunei, Egypt, Oman, Bahrain, and Sudan.

Iran	28.6
Saudi Arabia	24.9
Malaysia	11.1
UAE	08.7
Kuwait	06.3
Qatar	06.1
Turkey	02.6
Bangladesh	02.1
Indonesia	02.0
Pakistan	01.1
Bahrain	0.80
Sudan	0.60
Jordan	0.70
Oman	0.70
Egypt	0.80
Brunei	0.40
Others	01.6

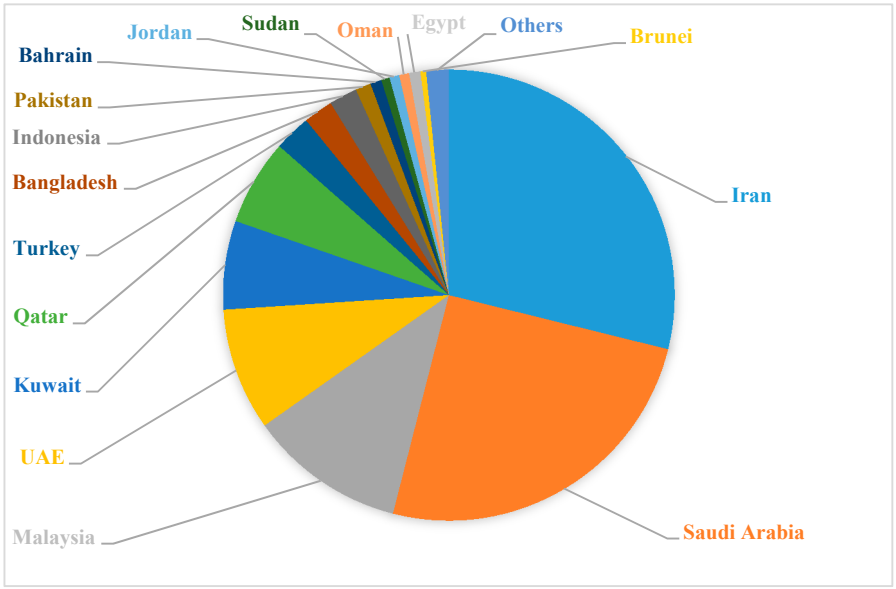

Figure 2. Domicile of Islamic banking assets per country: 3Q 2019 (in percentage) (Islamic Financial Services Industry Stability Report 2020, p. 15).

2.2. What Are the Objectives of Shariah (Maqasid al-Shariah)?

Maqasid al-Shariah refers to the highest objectives of Islamic laws set out to achieve socioeconomic justice [28]. It has three main components, namely, necessities/essential elements, complementary elements, and embellishments. According to the theory, necessities are essential elements of human life, the absence of which may cause damage or harm to human life. Examples are food, clothes, and shelter. The necessities are further sub-divided into five elements of preservation (See Figure 3). Shariah rulings aim primarily to protect these five elements from any harm. The complimentary elements are those items that complement the necessary. This relates to the fact that the negligence of such elements does not lead to the destruction of society, but rather to certain social suffering. In other words, they are required to relieve society's hardships. Examples of complimentary items are marriage, healthy food, communication tools, and means of transportation, among others. The embellishments are not mandatory in Shariah but contribute to the perfection of society if they are performed. Examples are charitable and philanthropic work. The concept is shown in Figure 3 below.

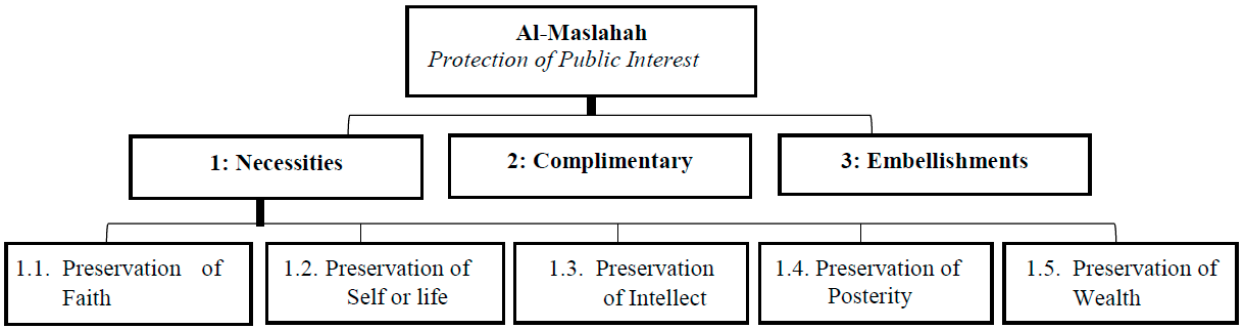

Figure 3. Maqasid al-Shariah theoretical framework of Al-Ghazali [28].

2.3. The United Nations Sustainable Development Goals (UN SDGs)

The United Nations Sustainable Development Goals (SDGs) are the collection of 17 goals with 169 targets and 232 indicators set to resolve diverse problems in the world in a sustainable manner [29]. The UN SDGs were launched in 2015 and are intended to be achieved by 2030. The UN SDGs mainly focus on achieving the five Ps, i.e., people, planet, prosperity, peace, and partnership [30]. The UN SDGs remains the area of pursuit for many researchers from the field of business sustainability [31]. The UN SDGs are shown in the table below.

The above Table 1 shows 17 SDGs. As the philosophy of the SDGs is based on the Triple Bottom Line (TBL) approach of sustainability. Therefore, in inconsistency with [29], this study categorized these goals into the three dimensions as below.

Table 1. United Nations Sustainable Development Goals.

Goal: 01	No Poverty	Goal: 10	Reduce Inequalities
Goal: 02	Zero Hunger	Goal:11	Sustainable Cities and Communities
Goal: 03	Good Health	Goal: 12	Responsible Consumption
Goal: 04	Quality Education	Goal: 13	Climate Action
Goal: 05	Gender Equality	Goal: 14	Life Below Water
Goal: 06	Clean Water and Sanitation	Goal: 15	Life on Land
Goal: 07	Renewable Energy	Goal:16	Peace and Justice
Goal: 08	Good Jobs and Economic Growth	Goal: 17	Partnership for the Goals
Goal: 09	Innovation and Infrastructure		

Table 2 shows the categorization of the 17 SDGs as per the triple bottom line. It shows that 12 SDGs purely dominate in separate sustainability dimensions, whereas the remaining 5 SDGs are interconnected, as per the Triple Bottom Line TBL.

Table 2. Categorization of the 17 SDGs into the triple bottom line (TBL).

Relevance	**Economic Sustainability**	**Environmental Sustainability**	**Social Sustainability**
Pure Dominance	• Goal 8 • Goal 9 • Goal 10	• Goal 6 • Goal 7 • Goal 13 • Goal 14 • Goal 15	• Goal 1 • Goal 4 • Goal 5 • Goal 16
Interconnected Goals	• Goal 2 • Goal 3 • Goal 17	• Goal 11 • Goal 12 • Goal 17	• Goal 2 • Goal 3 • Goal 11 • Goal 12 • Goal 17

2.4. Theoretical Foundation

The below Figure 4 illustrates the proposed alignment of Islamic banking sustainability indicators with the UN SDGs based on Maqasid al-Shariah (objectives of Shariah). It confirms whether a sustainability indicator is in line with the objectives of Shariah or not. It further suggests in which category of Shariah the sustainability indicators fall. It identifies whether the sustainability indicators are related to the necessities category of Shariah objectives (refer Figure 3), or whether they relate to the complementary or embellishment components of the Shariah objectives. The alignment of Islamic banking sustainability indicators with the UN SDGs is possible only when the sustainability indicators are confirmed to be in line with the objectives of Shariah. Therefore, the alignment of Islamic

banking sustainability indicators with the UN SDGs is predominantly dependent on the endorsement of Maqasid al-Shariah (objectives of Shariah).

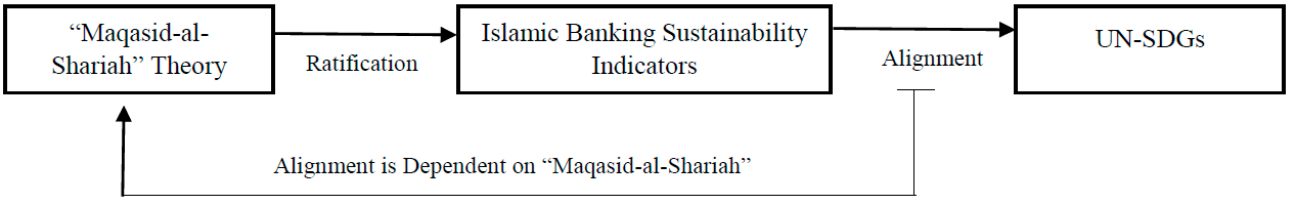

Figure 4. The nexus of Maqasid al-Shariah with the Sustainable Development Goals (SDG)s.

3. Methodology

3.1. Grounded Theory

This study is based on the grounded theory concept. The theory was presented by [32]. Grounded theory is a systematic methodology in the social sciences involving the construction of new theories and new concepts through methodical gathering and analysis of data. Although initially based on what had already been learned, the grounded theory allows for further exploration to provide a deeper understanding of a subject. The grounded theory does not specify any particular type of research strategy, data, or specific theoretical foundations to develop concepts [33,34]. The grounded theory is based on three elements: concepts, categories, and propositions [35–37]. The theory gradually emerged from the data: from data to codes, from codes to concepts, from the concepts to categories, and from categories to new theories, frameworks, or indexes. According to [32], axial coding is the obligatory element of the grounded theory, and if those coding paradigms are not followed, the proposed methods/concepts/framework provide inaccurate precision [34]. In the same vein, this study explains open coding and axial coding below.

3.2. Open Coding and Axial Coding Methods

According to [32], open coding deals with posting sanitizing questions related to the concept and categories of the study. According to [32], the generation of questions is based on the inductive knowledge of the researcher learned from the literature or experience in the field. Based on the list of questions offered by [32,34,38,39], for an efficient interpretation of the data this study constructed four questions related to each factor as per axial coding (see Tables A3 and A4 Appendix A). The second coding method is the axial coding method (ACM), which deals with making connections between different concepts and categories in the context of the grounded theory and designed questions. Reference [32] proposed the paradigm of axial coding based on the following factors, i.e., phenomena (context and intervening condition), causal condition, strategies, and consequences [34]. Though in the fourth edition of his book [38], he reduced the number of factors in the coding paradigm to three, i.e., action–interaction, conditions, and consequences. This study, however, to capture a holistic picture, establishes the connection between the concepts and categories based on the earlier factor of four [32]. Academic professors and industrial experts were involved in the overall creative process of open coding and axial coding.

3.3. The New ECA Method

To align the key sustainability indicators of the Islamic banks with the UN SDGs, this study proposes the new ECA method, the process for which is explained in detail below.

3.3.1. Step 1: Exploration (E)

This study anticipates that to align the indicators, instruments, or policies of any business (Islamic banks in this case) with the UN SDGs it is essential to first explore the pivotal indicators, instruments, or policies of the business using a systemic methodological process. For this purpose, methodologies such as principal component analysis (PCA), exploratory factor analysis (EFA), or frequency distribution, etc., can be used. These

methods will help the business firms identify their desired key indicators, instruments, or policies for alignment with the UN SDGs.

3.3.2. Step 2: Categorization (C)

In the second step, this study anticipates that the explored indicators, instruments, or policies must be categorized into broader dimensions/groups to make sure that they are in line with the existing business groups/dimensions. The categorization of the explored phenomena into different dimensions/groups will make the alignment easier and more rational. The group-wise alignment will allow the personnel from the group/dimension to work exclusively towards their identified SDGs. To categorize the explored business phenomena into different groups the axial coding method (ACM) must be used. The ACM is the process of the grounded theory used for establishing meaningful linkages between the categories (refer to Section 3.2 above).

3.3.3. Step 3: Alignment (A)

After the detailed exploration and categorization, the next step is to align the potential indicators, instruments, or policies with the respective UN SDGs. The alignment process brings synchronization between the groups/dimensions and the respective UN SDGs. The alignment process clarifies the role of authorities from different groups/dimensions towards policy formulation. For instance, the alignment process will clarify the role of economic, environmental, and social stakeholders of the firms to work explicitly towards the UN SDGs that are related to their department. In a way, the alignment process makes the compliance of business phenomena with the UN SDGs more specific. The process of alignment is subjected to the four factors of the axial coding paradigm. It implies that the process of alignment would be valid only for the present situation. In a future situation, the firms would require a fresh alignment. This is because the consequences, causal conditions, and phenomena can vary from time to time [34]. Therefore, keeping in mind the possible change to any of the four factors of the axial coding paradigm, it is prudent to conduct a fresh alignment in the future. Based on that, the firm may carry or drop certain past alignments based on the change in the consequences, causal conditions, or phenomena. To keep a check on the evolving business phenomena, causal conditions, and consequences, this study proposes a new SDG governance framework (Figure 7) that accounts for any change in the axial coding paradigm and acts based on the continuation or dropping of the alignment.

The detailed methodological process of this study is shown in Figure 5 below.

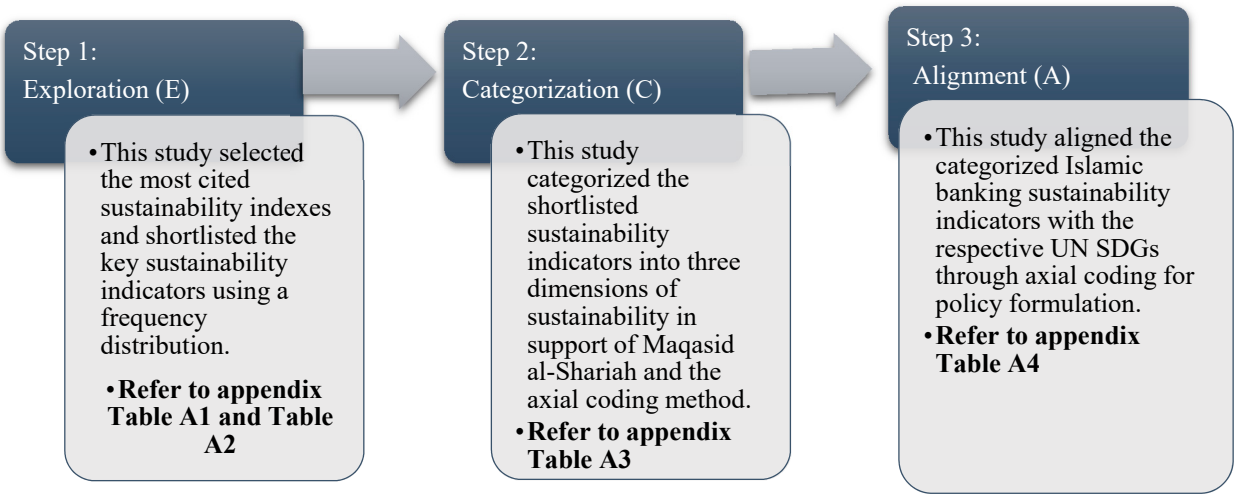

Figure 5. Methodological flow chart: the proposed ECA method.

3.4. Methodological Flow Chart

Figure 6 shows the detailed process of aligning vital business strategies (sustainability indicators in this case) with the SDGs. The SDG -Compass proposed by the Global Reporting Initiative (GRI) offers a framework for aligning business policies with the SGDs. However, the SDG -Compass is criticized on the ground that it lacks focus for exploring vital organizational goals. It only focuses on the implementation phase of the SDGs [39]. Emerging industries such as Islamic banking require detailed prior methodological knowledge before moving to the aligning phase. In the same vein, this study, by proposing antecedents (step 1 and step 2) to the SDG Compass, offers a reverse extension in the method. It will assist the Islamic banking industry in a more systematic way to align their vital business strategies with the SDGs.

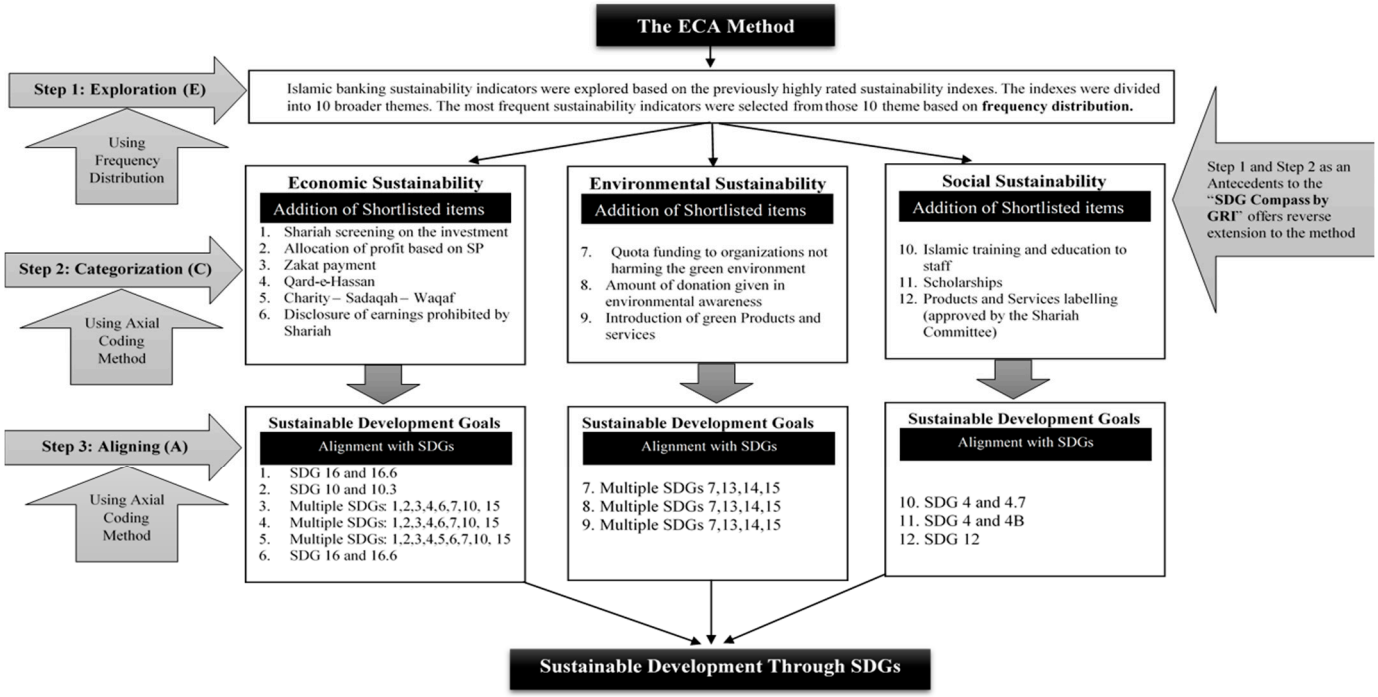

Figure 6. Flow chart of the proposed ECA method.

The above Table 3 shows the linkage of Islamic banks' sustainability indicators with the UN SDGs in support of Maqasid al-Shariah. The linkage of each Islamic bank's sustainability item is built with the appropriate UN SDGs (including the main goals and sub-targets). The following section shows commentary on each item in three different steps. In the first step, it shows how the sustainability indicator is categorized into the three dimensions of sustainability, i.e., economic, environmental, and social, based on the Maqasid al-Shariah theory. In the second step, it shows the alignment of the sustainability indicators with the UN SDGs. In the third step, it shows the policy implication to deal with the COVID-19 pandemic. Hence, the policy-based novelty of each sustainability indicator under this section is threefold, i.e., categorization (alpha), alignment (beta), and the COVID-19 responses based on alpha and beta.

Table 3. Categorization and the subsequent alignment of Islamic banking sustainability indicators with the UN SDGs.

Economic Sustainability Indicators (Profit)		
Sustainability Indicators	**Linkage with Maqasid al-Shariah**	**Alignment with the Sustainable Development Goals (SDGs)**
1. Shariah screening of investments	Necessities—preservation of faith	SDG 16 and sub-goal 16.6
2. Allocation of profit based on Shariah principles	Necessities—preservation of faith and wealth	SDG 10 and sub-goal 10.3
3. Zakat payment	Necessities—preservation of faith and wealth	SDGs 1, 2, 3, 4, 6, 7, 10, 15
4. Qard-e-Hassan	Complementary—preservation of self or life and posterity	SDGs 1, 2, 3, 4, 6, 7, 10, 15
5. Charity—Sadaqah—Waqaf	Embellishment	SDGs 1, 2, 3, 4
6. Disclosure of earnings prohibited by Shariah	Complementary—preservation of faith, self, and wealth	SDG 16 and sub-goal 16.6
Environmental Sustainability Indicators (Planet)		
Sustainability Indicators	**Linkage with Maqasid al-Shariah**	**Alignment with the Sustainable Development Goals**
7. Funding for organizations upholding green environment	Necessities—preservation of posterity and preservation of life	SDGs 7, 13, 14, 15
8. Amount of donations to environmental awareness	Necessities—preservation of posterity and preservation of life	SDGs 7, 13, 14, 15
9. Introduction of green products and service	Necessities—preservation of posterity and preservation of life	SDGs 7, 13, 14, 15
Social Sustainability Indicators (People)		
Sustainability Indicators	**Linkage with Maqasid al-Shariah**	**Alignment with the Sustainable Development Goals**
10. Islamic training and education for the staff	Complementary—preservation of intellect	SDG 4 and sub-goal 4.7
11. Offering scholarships	Complementary—preservation of intellect	SDG 4 and sub-goal 4B
12. Approval of new products and services by the Shariah committee	Necessities—preservation of faith	SDG 12

3.5. Economic Sustainability Indicators

The categorization and subsequent alignment of the shortlisted Islamic banking economic sustainability indicators are consistent with the doughnut economic model [40]. The doughnut framework suggests considering the efficiency of an economy to the degree that people's needs are fulfilled without overshooting the ecological ceiling of the world. Both the doughnut and the SDGs are related to sustainable development. However, the scope of the SDGs is much wider compared to the doughnut economic model.

3.5.1. Shariah Screening of Investments

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

Based on the principles of Maqasid al-Shariah, this article suggests that the instrument of "Shariah screening of investments" falls under the category of necessities and the subcategory of "preservation of faith." Islam forbids investments in the haram business (forbidden by Islamic laws), such as gambling. This is because in such trade practices the element of free and fair exchange of goods and services is not observed, and rather are based on deceit and dishonesty [41]. Therefore, it is the responsibility of the Shariah committee to screen all investment of the Islamic banks for the preservation of faith. Shariah screening of investments is categorized in the economic sustainability dimension based on the philosophy that once the Shariah committee certifies an investment of the Islamic bank

is in line with objectives of Shariah, it attracts more investors, and holistically it positively affects the economic sustainability of Islamic banks.

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

The instrument of Shariah screening of investments may serve SDG 16, i.e., peace, justice, and strong institutions, and its sub-target 16.6, which is about developing transparent, accountable, and effective institutions at all levels. Shariah screening of investments offers great transparency and accountability based on Islamic laws in developing effective institutions. Shariah objectives aim to promote social welfare (Al-Maslahah); therefore, the instrument of Shariah screening of investments will ensure the prevention of investments in the inappropriate haram business (forbidden by Islamic laws), such as gambling, which generally violates the business objectives of free and fair exchange.

- *The COVID-19 Response: Based on Alpha and Beta*

The current scenario demands fair investment (Shariah screening) and strong institutions to fight the pandemic. [42] alluded that Shariah screening of investments provided hedging benefits to various market stakeholders during the pandemic. Providing such benefits during the pandemic shows the unique quality of a financial system in a time of crisis. Against that background, it shows that Shariah screening of investments helped build strong institutions during the pandemic. Hence, the following proposition was developed.

Proposition 1. *The alignment of Shariah screening of investments with UN SDG 16 and sub-target 16.6 will help build strong institutions to fight the COVID-19 pandemic.*

3.5.2. Allocation of Profit Based on Shariah Principles

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

The article claims, based on the principles of Maqasid al-Shariah, that the allocation of profit based on Shariah principles falls within the main category of necessities and the subcategories of faith and wealth preservation. Distribution of profit in Islamic banks is directly linked to religiosity, which directs Islamic banks to equally distribute income and minimize inequality. In a way, it preserves the wealth of stakeholders and thereby is incorporated into the economic dimension of sustainability.

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

This study made an alignment of the instruments with UN SDG-10 and sub-goal 10.3, which alludes to reducing inequalities of outcomes by eradicating discriminatory principles and laws. The Shariah objectives/laws aim to promote socioeconomic justice [28]. Therefore, the allocation of profit based on Shariah principles will eradicate discriminatory principles by promoting the fair distribution of profit and hence strongly supports UN SDG 10.3.

- *The COVID-19 Response: Based on Alpha and Beta*

Profit-sharing in Islamic banks is different than conventional banks, i.e., in Islamic banks the share of profit increases only once the bank makes a profit, whereas in conventional banks the customers get a fixed rate even if the bank is not earning likewise in the pandemic [43]. Furthermore, Islamic banking clients get a high profit once the bank makes more profit, whereas in conventional banks the clients do not receive any additional share of the profit even when the bank makes more profit [43]. This situation is reducing the inequalities of outcomes for the Islamic banking clients. Even in times of crisis, unlike conventional banks, Islamic equity funds provide hedging benefits to various market stakeholders, such as during the pandemic. Times of crisis can be used as an opportunity by Islamic banks to invest in policy formulation for reducing inequalities [25]. Islamic banks are offering a practical solution to it, hence, it can be idealized by other businesses to

reduce inequalities and promote fair principles for profit-sharing during the COVID-19 pandemic. Hence, the following proposition was developed.

Proposition 2. *Aligning the allocation of profit based on Shariah principles with UN SDG 10 and sub-target 10.3 will help in fighting the COVID-19 pandemic by reducing inequalities of outcomes through eradicating discriminatory principles and laws.*

3.5.3. Zakat Payment

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

In Islam, zakat is a religious obligation or tax treated as the second highest in rank after prayers. It refers to a religious obligation where an individual is required to pay at the ratio of 2.5% above the minimum amount of savings per year as almsgiving [44]. This article posits that according to the principles of Maqasid al-Shariah, the zakat payment instrument falls under the main category of necessities and the subcategories of faith preservation and wealth preservation. This is because paying zakat is one of the five essential pillars of Islam. Furthermore, according to Islamic literature, it purifies and increases wealth. It is categorized into an economic dimension of sustainability as it boosts income. The payment of zakat and its transparent reporting, from the perspective of Islamic banking shareholders, would increase the goodwill of Islamic banks towards their stakeholders. As a result, the bank will obtain more funds from various stakeholders to enhance Islamic banks' economic viability in a positive direction.

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

Zakat payment is a unique sustainability instrument in Islamic banking that may serve multiple UN SDGs. Zakat is paid with the aim of supporting the disadvantaged people in society [45]. In the same vein, this study aligned the instrument of zakat to UN SDGs 1, 2, 3, 4, 6, 7, 10, and 15 because these goals are directly related to the needs of disadvantaged people. Hence, aligning and channeling zakat with the goals ensure compliance of the Islamic banks with the UN SDGs.

- *The COVID-19 Response*

Haider Syed, et al. [4], also argued that zakat payment can be used as a tool for poverty alleviation during the COVID-19 pandemic. Islamic banks can design a portfolio by channeling zakat to support the disadvantaged sector of society. For instance, the pandemic has directly affected the food, poverty, health, drinking water, and education of multiple stakeholders. The instrument of zakat can be channeled into the following SDGs: goal 1 (no poverty), 2 (zero hunger), 3 (good health), 4 (quality education), 6 (clean water and sanitation), 7 (renewable energy), 8 (good jobs and economic growth), 10 (reducing inequalities), and 15 (life on land) for sustainable development. The Islamic bank may design a diversified portfolio with the help of a micro-examination to identify which area of the country/region/world requires which kind of assistance and what is most urgently required, whether it be food, medicines, drinking water, energy, or jobs, and to channel zakat to the neediest areas accordingly. In the way, it will serve multiple UN SDGs and will promote sustainable development across the country/region/world. Based on the discussion the following proposition was developed.

Proposition 3. *Channeling the zakat payment to UN SDGs 1, 2, 3, 4, 6, 7, 10, and 15 can assist in poverty alleviation, reducing hunger, promoting health care, offering quality education, providing clean water and sanitation, facilitating renewable energy, protecting good jobs and economic growth, reducing inequalities, and uplifting life on land during the distressing impacts of the COVID-19 pandemic.*

3.5.4. Qard-e-Hassan (Benevolent Loans)

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

Qard-e-Hassan is defined as the interest-free loans granted to persons in need for a specific period [46]. This study classified Qard-e-Hassan as a complementary item to the subcategories of preservation of self or life and preservation of posterity based on the principles of Maqasid al-Shariah. The Qard-e-Hassan financing facility is more applicable in poor or underdeveloped countries where it can serve to remove hardship from society and life. It is incorporated into the economic dimension of sustainability because the provision of Qard-e-Hassan to poor customers would not only increase the goodwill of Islamic banks in the minds of their customers but also of the general public. As a result, Islamic banks will attract more deposits from other stakeholders, which may strengthen their economic sustainability positively.

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

The instrument of Qard-e-Hassan (interest-free loans) can also target multiple UN SDGs. This loan aims to assist the needs of stakeholders for a shorter period. In line with that, this study aligned the Islamic banking sustainability instrument of Qard-e-Hassan with UN SDGs 1, 2, 3, 4, 6, 7, 10, and 15. These goals are interconnected with each other. Improvement in one goal, for instance no poverty, as a subset brings an improvement in the other goals as well. For example, alleviating poverty enhances the purchasing power of stakeholders, which allows them to afford food, health services, water, and energy. Against that background, this study posits an alignment between Qard-e-Hassan with multiple UN SDGs.

- *The COVID-19 Response: Based on Alpha and Beta*

We posit that the payment of Qard-e-Hassan to skilled employees/entrepreneurs of Small and Medium-sized Enterprises SMEs who lost their jobs/business during the pandemic will bring positive change in the other interconnected UN SDGs. For a short period, Islamic banks need to increase the amount of Qard-e-Hassan mostly to these skilled workers. This is because they are most likely to generate economic activity with less training and effort required, because they are already trained enough and have experience in running certain small enterprises. At the same time, based on their business expertise they are most likely to repay the loan to the Islamic banks within the specified period. Haider Syed, et al. [4] alluded that Qard-e-Hassan can be used to alleviate poverty (SDG 1) during the pandemic. Poverty alleviation increases purchasing power, which as a subset allows a stakeholder to purchase better health services, buy food and drinking water, and afford electricity, etc. Hence, the following proposition was developed.

Proposition 4. *The payment of Qard-e-Hassan to skilled workers can lead to poverty alleviation; reduce hunger; open up access to good health care, quality education, clean water and sanitation, and renewable energy; reduce inequalities; and uplift life on land during the COVID-19 pandemic.*

3.5.5. Donating to Charity through Sadaqah and Waqf

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

According to the principles of Maqasid al-Shariah, this article posits that the instrument of donating to charity through the Islamic instruments of Sadaqah and Waqf falls under the embellishment category. In Islamic terminology, "Sadaqah" is defined as a voluntary offering of something without expecting a substitute in return with the sole intention of pleasing Allah, whereas "Waqf" refers to a charitable endowment of donating a plot, building, or land. In Islam, charity payment is not mandatory, but it will lead to perfection in society if one pays it. In the context of Islamic banks, paying charity through Sadaqah and Waqf is a part of their operations. Islamic banks are required to channel the income derived from unclear or tainted activities to charitable bodies, including Waqf institutions.

Circulating wealth to the people through charity, Sadaqah and Waqf have upgraded the image of Islamic banks and subsequently improved economic sustainability [19].

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

The instrument of charity can also serve multiple UN SDGs. Charity (Sadaqah and Waqf) are used for poverty alleviation and socioeconomic development [47]. In line with that, this study aligned the instrument with UN SDGs 1, 2, 3, and 4. This is because these goals are directly related to poverty alleviation and socioeconomic development.

- *The COVID-19 Response: Based on Alpha and Beta*

According to the new research published by the United Nations University UNU-WIDER (https://www.wider.unu.edu/news/press-release-covid-19-fallout-could-push-half-billion-people-poverty-developing-countries), the pandemic can increase global poverty to about half of a billion people, affecting about 8% of the global population. This increase will affect the UN's agenda of achieving zero poverty by 2030. In addition, according to the world food program, the pandemic may expose around 130 million additional people to hunger by the end of 2020 (https://insight.wfp.org/covid-19-will-almost-double-people-in-acute-hunger-by-end-of-2020-59df0c4a8072). Similarly, it will affect the UN's agenda of achieving zero hunger by 2030. Furthermore, according to the United Nations Educational, Scientific and Cultural Organization (UNESCO) (https://en.unesco.org/covid19/educationresponse), the pandemic has left around 1.6 billion students out of school, which has caused severe mental health issues. Therefore, the instrument of charity by Islamic banks can be targeted towards these goals of no poverty (goal 1), zero hunger (goal 2), good health (goal 3), and quality education (goal 4) to reduce the undesirable impacts of the COVID-19 pandemic. Hence, the following proposition was developed.

Proposition 5. *Channeling the amount of charity to UN SDGs 1, 2, 3, and 4 during the pandemic can help poverty alleviation, reduce hunger, promote good health care, and can assist in providing quality education to disadvantaged and deprived stakeholders.*

3.5.6. Disclosure of Earnings Prohibited by Shariah

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

According to the principles of Maqasid al-Shariah, this article posits that the disclosure of earnings prohibited by Shariah is complementary to the preservation of faith, self, and wealth. This is because in Islam all financial transactions must be transparent, accurate, and fully recorded [48]. All income received from non-Shariah sources must be fully audited and managed, otherwise they can affect the economic sustainability of Islamic banks [49]. It is the responsibility of the Shariah committee to identify such income and dispatch it to charity funds [50,51].

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

The Islamic banking sustainability instrument "the disclosure of earnings prohibited by Shariah" may serve UN SDG 16 and its sub-goal 16.5, which alludes to building transparent, accountable, and effective institutions at all levels. These earnings are channeled by the Islamic banks to charity funds because they violate the principles of Islamic business. Dispatching the earned amount from the profits of Islamic banks ensures greater transparency, accountability, and business effectiveness as well. Consonant with that, this study aligned this instrument with UN SDG 16 and sub-goal 16.5, because that sustainability instrument of Islamic banks will support UN SDG 16 and 16.5.

- *The COVID-19 Response: Based on Alpha and Beta*

Opportunities can be created by investing in policy formulation at the time of crisis. The role of the Shariah committee in dispatching earned money to charity funds based on the violation of business principles is exemplary. It consequently helps build strong

institutions. Strong institutions are vital to fighting the COVID-19 pandemic. Hence, the following proposition was developed.

Proposition 6. *Aligning the sustainability instrument "disclosure of earnings prohibited by Shariah" with UN SDG 16 and its sub-target 16.5 will help build transparent, accountable, and effective institutions in fighting against the COVID-19 pandemic.*

3.6. Environmental Sustainability Indicators

The categorization, alignment, and policy propositions based on the environmental sustainability indicators are provided below.

3.6.1. Funding for Organizations Upholding a Green Environment

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

The above sustainability indicator is related to the main category of necessities and the subcategories of preservation of posterity and life preservation, based on Maqasid al-Shariah. Jusoff, et al. [52], by quoting from Islamic sources, argued that humans are the stewards of the earth. Matali [53] argued that every Muslim must preserve the ecosystem. Based on the strong existing nexus between the above instrument and green environment it is integrated into the environmental sustainability dimension.

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

This sustainability item may serve multiple UN SDGs related to the environment. This instrument of Islamic banks is linked to supporting the green environment. In line with that, this study proposes aligning this instrument with UN SGDs 7, 13, 14, and 15. This is because these UN SDGs are directly related to preserving the environment. Hence, the alignment will ensure greater compliance by Islamic banks with the sustainable development agenda of the United Nations.

- *The COVID-19 Response: Based on Alpha and Beta*

The shortage of power can significantly magnify the recovery process from COVID-19. Similarly, the availability of clean water and proper sanitation is vital for maintaining hygiene, which is a fundamental element in fighting the virus. These facts demand Islamic banks to consider climate actions more strictly during their funding process. The time demands that Islamic banks must increase their funding to organizations that focus on renewable energy, clean water, biodiversity, and climate action projects. These fundamental steps will help in curbing the current pandemic of COVID-19 and will limit the chance of future pandemics. Hence, the following proposition was developed.

Proposition 7. *Channeling the amount of funding to organizations upholding a green environment to UN SDGs 7, 13, 14, and 15 can lead to the provision of affordable and clean energy, better climate actions, assisting life below water, and more sustainable life on land during the COVID-19 pandemic.*

3.6.2. Amount of Donations to Environmental Awareness

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

This research, based on Maqasid al-Shariah, notes that the above instrument falls within the main category of essential/necessities and the subcategory "preservation of life and preservation of posterity." This is because every Muslim must preserve the ecosystem and planet [53]. Based on the existing nexus between this item and the environment, this study categorized the item into the environmental sustainability dimension.

- *Alignment of Sustainability Indicator with UN SDGs (Beta)*

This sustainability item may also serve multiple UN SDGs related to the environment. This instrument of Islamic banks is linked to supporting a green environment. In line with that, this study proposes aligning the instrument with UN SGDs 7, 13, 14, and 15. This is because these UN SDGs are directly related to preserving the environment.

Hence, the alignment will ensure greater compliance by Islamic banks with the sustainable development agenda of the United Nations.

- *The COVID-19 Response: Based on Alpha and Beta*

A healthy ecosystem is our only guarantee to fight the COVID-19 pandemic and our lives depend on the health of the planet. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) (https://en.unesco.org/news/covid-19-ocean-ally-against-virus), a bacteria found in the depth of oceans is used for testing to rapidly detect COVID-19. Khalil, et al. [54] argued that higher biodiversity lowers the risk of spreading infectious diseases, a process called the "dilution effect." Therefore, this is the right time for Islamic banks to channel their environmental donations towards the environmental areas identified in the UN SDGs that are sourcing natural material to fight the pandemic. Islamic banks can take the lead in this regard by setting up a special unit devoted to directly channeling environmental donations to the UN SDGs that will ultimately help in fighting the COVID-19 pandemic. Hence, the following proposition was developed.

Proposition 8. *Aligning donations to environmental awareness with UN SDGs 7, 13, 14, and 15 can lead to the provision of affordable and clean energy, better climate actions, assist life below water, and promote sustainable life on land during the COVID-19 pandemic.*

3.6.3. Introduction of Green Products and Services

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

Following the principle of Maqasid al-Shariah, the above instrument is related to the main category of necessities and the subcategory of preservation of posterity and preservation of life. This instrument is incorporated into environmental sustainability based on the principle of Maqasid al-Shariah, since Islam commands every Muslim to conserve the ecosystem [53].

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

This instrument of Islamic banks may serve multiple UN SDGs related to the environment. The instrument of green product and services is aimed at supporting the environment. In the same vein, this study posits the alignment between this sustainability instrument with UN SDGs 7, 13, 14, and 15. The proposed alignment will support the sustainable development agenda of Islamic banks based on the UN SDGs related to the environment.

- *The COVID-19 Response: Based on Alpha and Beta*

The pandemic has allowed an opportunity for every business sector [25] to transform and introduce green products and services in compliance with the UN SDGs. This is because linking products and services with the UN SDGs offers great security, and it is expected that those products and services will be least affected in future pandemics due to their prudence. Sukuk green bonds and green technology financing are efficient Islamic instruments that have the potential to curb the pandemic. Based on the discussion the following proposition was developed.

Proposition 9. *Alignment of the introduction of green products and services with UN SDGs 7, 13, 14, and 15 can lead to the provision of affordable and clean energy, climate action, and assist life below water and sustainable life on land during the COVID-19 pandemic.*

3.7. Social Sustainability Indicators

The categorization, alignment, and policy propositions based on the social sustainability indicators are provided below.

3.7.1. Islamic Training and Education for Staff

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

Based on Maqasid al-Shariah, the above instrument is complementary to the necessity category of preservation of intellect. This is because the protection of intellect in Islam is not obligatory. However, if Islamic banks operate through education or training to maintain the intelligence of their workers, it would pave the way for them to conduct Islamic banking operations effectively. Julia and Kassim [55] argued that Islamic banks compared to conventional banks are efficiently assisting their staff in the preservation of intellect in terms of awareness of green products. The current study integrated this item into the social sustainability dimension because the impact of banking staff is directly linked to the people and society.

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

This instrument can target SDG 4 (quality education) and its sub-goal 4.7, which ensures learning new knowledge through collaborative work for sustainable development. As the main aim of the Shariah objectives is to achieve socioeconomic justice and development [28], in line with the Shariah principles, Islamic training and education for staff must ensure quality education aimed at sustainable development. Hence, this alignment will ensure the contribution of the Islamic banks towards SDG 4 and sub-goal 4.7.

- *The COVID-19 Response: Based on Alpha and Beta*

The COVID-19 pandemic is unfolding into a great educational crisis. Consonant with that, UNESCO launched global education collation in March 2020 (https://en.unesco.org/news/covid-19-ocean-ally-against-virus) aimed at designing innovative solutions. Islamic banks can avail of this opportunity by encouraging their staff to participate in such collaborative works to learn how the banking staff can play a role in tackling the pandemic at different levels, either directly or indirectly. Through such platforms, Islamic banking staff can also share the Islamic version of the solution to fight the COVID-19 pandemic. This transfer of knowledge and sharing experiences may educate banking staff in sustainably dealing with the virus. Based on the discussion the following proposition was developed.

Proposition 10. *Aligning training and education for the staff with UN SDG 4 and sub-goal 4.7 may lead to learning new knowledge through collaborative work that will assist in policy formulation for fighting the COVID-19 pandemic.*

3.7.2. Offering Scholarships

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

According to Maqasid al-Shariah, offering scholarships is considered complementary to the basic category of preservation of intellect. It is incorporated into the social sustainability dimension because providing scholarships to multiple stakeholders will raise the quality of education in society and will uplift social standards as well.

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

This instrument is directly targeting SDG 4 (quality education) and sub-goal 4B, which focuses on expanding the number of scholarships to developing countries. Therefore, aligning the Islamic banking sustainability instrument of scholarships with UN SDG 4B will promote quality education in supporting the sustainable development agenda of the UN.

- *The COVID-19 Response: Based on Alfa and Beta*

According to UNESCO (https://en.unesco.org/covid19/educationresponse), COVID-19 has affected more than one billion students, which accounts for about 67% of total enrolled students globally. There are fears that due to the current turmoil students from mostly underdeveloped or developing countries may completely lose out on their education. This can result in more child-labor cases. Therefore, this is the most appropriate time

for Islamic banks to start offering more scholarships to peoples from mostly underdeveloped countries to avoid child-labor cases. In addition, they should help the world enroll students back to campuses that were affected by the COVID-19 pandemic. Based on the discussion the following proposition was developed.

Proposition 11. *Alignment of the sustainability indicator of scholarships with UN SDG 4B during the COVID-19 pandemic will assist students from developing countries in getting a quality education and subsequently mitigate the risk of child labor and child trafficking.*

3.7.3. Approval of New Products and Services by the Shariah Committee

- *Categorization of Sustainability Indicator into Respective Sustainability Dimension (Alpha)*

Based on the principles of Maqasid al-Shariah, the above sustainability item is linked to the main category of necessities and its subcategory of preservation of faith. It is linked with the preservation of faith because Islam prohibits dealing in haram (prohibited by Islam) products and services. Muslims must also preserve faith while doing business. It is included in the social sustainability dimension because nowadays most of the banking services and products are provided online or through electronic machines that are directly associated with people and society. For instance, the content in the advertisements of Islamic banks must be ethically and socially acceptable to the stakeholders. The delivery of products and services should not lead to any sort of waste generation, carbon footprints, or other forms of social or environmental degradation. Ignoring ethical elements in the delivery of products and services to society may directly affect the social sustainability of Islamic banks. Hence, the Shariah committee must ensure the elements of society before approving any products or services. This is because the intended objectives of the principle of Shariah are to achieve socioeconomic justice for individuals and society and to enhance welfare in society.

- *Alignment of Sustainability Indicator with the UN SDGs (Beta)*

This instrument may assist in targeting UN SDG 12, which highlights responsible consumption and production. The Shariah committee of Islamic banks in support of Shariah objectives (which aim at achieving socioeconomic justice) are bound to provide approval only for those products and services that achieve socioeconomic justice. Hence, the alignment with UN SDG 12 will promote responsible production and consumption aimed at a sustainable development agenda.

- *The COVID-19 Response: Based on Alpha and Beta*

The pandemic has allowed an opportunity to shift towards more responsible consumption related to products and services. Humans' wants are unlimited, but the planet has limited resources to fulfil those needs. Humans must appreciate and understand the limits to which they can push nature before it starts to react negatively. Businesses must display those limits in their production and consumption patterns to uplift environment and society. The objectives of Shariah are to achieve socioeconomic justice for individuals and society and to enhance welfare in society. Based on these principles, the Shariah committee prudently monitors any new products and services offered by Islamic banks to promote responsible consumption and production. In a time of crisis, considering the impact of new products and services offered to society and the environment will mitigate the distressing impact of the COVID-19 pandemic in a sustainable manner. Based on the discussion the following proposition was developed.

Proposition 12. *The alignment of sustainability indicator "approval by the Shariah committee of new products and services" with UN SDG 12 can reduce the distressing impact of COVID-19 through promoting responsible consumption and production.*

4. Conclusions

This article posits an alignment between Islamic banking sustainability indicators and the United Nations Sustainable Development Goals (UN SDGs) to provide timely Islamic-based policy guidelines for reducing the diverse impacts of the COVID-19 pandemic on the triple bottom line (people, planet, and profit) and to achieve sustainable development as well. For this process, in the first place, the article identifies the key Islamic banking sustainability indicators (see Table A2 Appendix A). In the second place, this study categorizes the selected sustainability indicators in the triple bottom line (TBL) in support of the principles of Maqasid al-Shariah and the axial coding method (see Table A3 Appendix A). In the third place, this study establishes the link between the categorized sustainability indicators and the UN SDGs in support of the axial coding method for policy formulation (see Table A4 Appendix A). This study named the new method the ECA method. The new ECA method (see Figure 6) offers a reverse extension to the SDG Compass designed by the Global Reporting Initiative (GRI) to align business policies with the UN SDGs. The SDG Compass is often criticized on the ground that it lacks focus in exploring vital organizational goals, and it only focuses on the implementation phase of the SDGs [39]. Emerging industries such as Islamic banking require detailed prior methodological knowledge such as the exploration and categorization of vital business strategies before moving on to the aligning phase. The new method will assist the Islamic banking industry in a more systematic way of aligning their vital business strategies with the SDGs. The propositions offered should help guide practitioners of the Islamic banking industry to set up a separate sustainability division aimed at integrating Islamic banking sustainability indicators with the UN SDGs with the aim of mitigating the impact of COVID-19 on the triple bottom line. The commentary (in Section 3), can serve as a base in the process of developing the proposed sustainability division in fighting the virus based on Islamic principles. These structural reforms in the short run will assist Islamic banks to play their social role in defeating the virus by offering Islamic solutions, whereas in the long run, they will assist Islamic banks to promote the UN agenda of sustainable development.

4.1. Theoretical Implications

In terms of theoretical contribution, this article offers a novel approach for establishing a theoretical connection between sustainability indicators and Maqasid al-Shariah (objectives of Shariah). Secondly, after the ratification of the sustainability indicators, this study linked it with the UN SDGs. Hence, the linkage of Islamic sustainability items with the UN SDGs is dependent on Maqasid-al-Shariah. This highlighted the predominant connection between Maqasid al-Shariah (objectives of Shariah) and the UN SDGs. This study closed the theoretical gap by first identifying and then linking Islamic banking sustainability indicators with the UN SDGs in support of Maqasid-al-Shariah. This made it easier for future researchers to ratify future Islamic banking sustainability indicators accordingly and to link them with the UN SDGs. More importantly, the new ECA method proposed by this study may evolve into an ECA theory for the SDGs in the future with further advancement and refinement.

4.2. Social/Practical Implications

In the context of the COVID-19 pandemic, this article offers practical solutions to fight the impact of the crisis faced by the world. The process of aligning Islamic banking sustainability indicators with the UN SDGs will provide a roadmap to recovery from the catastrophe caused by COVID-19. This is because the UN SDG framework is a comprehensive framework covering multifarious aspects for sustainable development. Considering the UN SDGs in terms of the Islamic banking instruments will consequently mitigate the severe impacts of COVID-19 on people–society, planet–environment, and profit–economy. Firstly, it could unlock the potential of the Islamic banking industry (fighting the virus with Islamic instruments) for various stakeholders. Most importantly, it could help the world recover from the distressing impacts of the pandemic in a more sustainable manner.

4.3. Policy Recommendations

This study, by proving the anteceding steps for aligning sustainability practices of Islamic banks with the UN SDGs, offers a reverse extension of the SDG Compass designed by the Global Reporting Initiative (GRI) to assist business firms in aligning their business policies with the SDGs. The SDG Compass lacks focus on exploring vital organizational goals, rather only focusing on alignment [39]. Therefore, by proposing the antecedents (step 1 and step 2 in Figure 6), this study offers various policy insights to the practitioners of Islamic banks. In the short run, they must consider the key Islamic banking sustainability indicators (step 1 in Figure 6) in recovery plans. As their alignment is already established with the UN SDGs (steps 2 and 3 in Figure 6), they will mitigate the diverse impacts of the COVID-19 pandemic on the triple bottom line (people, planet, and profit). In the long run, a dedicated SDGs division must be developed in Islamic banks for streamlining (step 1 and step 2 in Figure 6). Achieving the short- and long-run transformation and compliance with the UN SDGs requires an effective governance framework. In the same vein, this study proposes a framework for SDG governance in Figure 7 below.

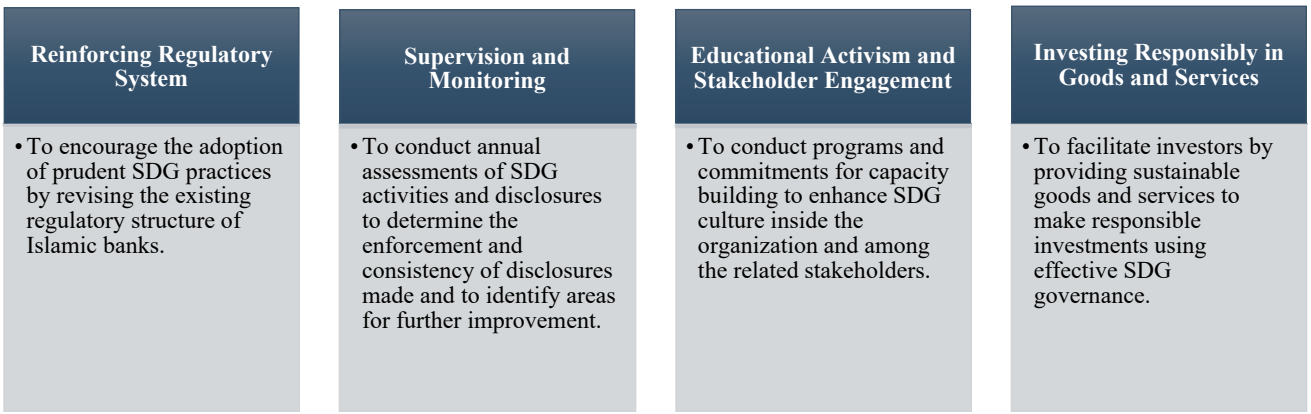

Figure 7. Proposed SDG governance framework for the practitioners of Islamic banking for policy.

Figure 7 shows the proposed framework for SDG governance. This will offer policy insights for identification, supervising, and monitoring SDG-related policies at the bank level. Eventually, it will help Islamic banks explore their vital sustainability indicators, categorize them in the triple bottom line, and eventually to align themselves with the UN SDGs to tackle COVID-19 and similar pandemics in the future. Moreover, these transformations will promote sustainable development.

4.4. Avenues for Future Research and Recommendations

This article encourages future work on identifying other key Islamic banking sustainability indicators and to establish a link with the UN SDGs using the ECA method. This will assist the practitioners of Islamic banking in their policy formulation. Holistically, it will ensure the achievement of the sustainable development agenda.

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Appendix A

Appendix A.1. Shortlisting Key Islamic Banking Sustainability Indicators (EXPLORATION)

To identify the key Islamic banking sustainability indicators, in the first stage, the authors shortlisted the most quoted sustainability measurement indexes that are present in Islamic banking as highlighted in extant literature (refer to Table A1 below). First, the indexes were selected based on the number of citations of scholarly articles and the rankings of the journals. Next, the broader themes of all the indexes were identified. It was found that those indexes mainly used 10 broader themes (see Table A1). In the third step, the dimensions that had frequency distributions above 50 were shortlisted, and further in the process, the top six sustainability dimensions were selected based on their high frequency, i.e., above 50%. Under the six broader themes, the sustainability indicators that appeared in a minimum of three indexes were selected. In the process, the top 12 sustainability indicators were identified (refer to Table A2). The shortlisted sustainability indicators were first verified based on Maqasid-al-Shariah to be in line with Shariah principles and were then separated into the three dimensions of sustainability based on axial coding. Even though the indicators were selected from the indexes used in Islamic banking, their ratification according to Shariah objectives was required. This is because each sustainability index is based on universal (conventional) items and industry-specific items [12]. Therefore, using the principles of Maqasid-al-Shariah, it was assured that the selected sustainability indicators are in line with Shariah objectives and follow the industry-specific Islamic banking philosophy.

Table A1 illustrates the detailed process of segregating the previously used sustainability measurement indexes from Islamic banking into broader themes. It was found that the top sustainability measure indexes have mainly used 10 broader dimensions. Code 1 shows that the index considered sustainability items related to a specific theme and zero otherwise. The transformation process shows that the top sustainability themes for consideration by Islamic banking are "employee," "community and society," "Shariah governance," "products and services," and "environment." The subsequent Table A2 first shows sustainability indicators from the shortlisted broader themes, which involved Islamic principles or Islamic wordings with the indicators. Secondly, it shows the shortlisting of sustainability indicators that appeared in at least three indexes. Details about the shortlisted indicators are presented below in Table A2.

Table A2 shows the selection process of Islamic indicators from the six shortlisted themes based on the frequency distribution. It only shows sustainability indicators from the selected broader themes that involved Shariah principles and were in line with Islamic banking philosophy. Conventional indicators from the previously used indexes were not selected. Only the industry-specific (Islamic banking) indicators were selected. With the help of Maqasid al-Shariah, the shortlisted indicators were ratified to be in line with Shariah principles and subsequently, their linkage with the UN SDGs was established.

Appendix A.2. Categorizing the Shortlisted Sustainability Indicators (CATEGORIZATION)

Table A3 shows the detailed categorization process of shortlisted sustainability indicators in the triple bottom line as per the axial coding method.

Appendix A.3. Alignment of the Categorized Sustainability Indicators with the UN SDGs (ALIGNMENT)

Table A1. Broader themes from previous sustainability indexes used for measuring sustainability practices in the Islamic banking industry.

Broader Themes from Sustainability Indexes		Platonova, et al. [22]	Amran, et al. [56]	Aribi and Arun [57]	Mallin, et al. [12]	Aribi and Gao [58]	Farook, et al. [17]	Rahman, et al. [59]	Hassan and Harahap [15]	Othman and Thani [60]	Haniffa and Hudaib [61]	Maali, et al. [62]	Dusuki [63]	Frequency Distribution	Percentage
1. Employees	1. Employment 2. Commitment to employees 3. Employees 4. Employees 5. Employees 6. Employees 7. Employees 8. Employees 9A. Workers' health and safety 9B. Workers' education and training 9C. Fair treatment of workers and applicants 9D. Fostering Islamic values among staff 10. Employees 11. Commitment towards employees	1	1	1	1	1	1	1	1	1	1	1	1	12	100
2. Community and Society	1. Commitment to community 2. Community development and social goals 3. Community 4. Society 5. Community 6. Other aspects of community involvement 7A. Financing companies not violating human rights 7B. Financing SMEs, providing affordable service to deprived areas 7C. Supporting charities and community projects 7D. Solving social problems 8. Community involvement 9. Commitment to society	1	1	0	1	1	1	1	0	1	1	1	1	10	83

Table A1. *Cont.*

Broader Themes from Sustainability Indexes		Platonova, et al. [22]	Amran, et al. [56]	Aribi and Arun [57]	Mallin, et al. [12]	Aribi and Gao [58]	Farook, et al. [17]	Rahman, et al. [59]	Hassan and Harahap [15]	Othman and Thani [60]	Haniffa and Hudaib [61]	Maali, et al. [62]	Dusuki [63]	Frequency Distribution	Percentage
3. Governance/Shariah Compliance	1. Governance 2. Shariah compliance 3. Corporate governance and Shariah-compliant corporate governance 4. Corporate governance 5. BOD and top management 6. Shariah Supervisory Board SSB 7. Sharia opinion—unlawful (haram) transaction 8. Islamic value and SSB 9. Shariah Supervisory Board 10A. Unusual supervisory restrictions 10B. Unlawful (haram) transactions 10C. Sharia Supervisory Council	0	1	1	1	1	1	1	1	1	1	1	0	10	83
4. Zakat/Charity/ Qard-e-Hasan	1. Zakat, charity and benevolent funds 2. Zakat, charity, donations, and Qard-e-Hassan 3. Charity and zakat 4. Zakat, charity, and benevolent loans 5. Zakat, Qard-e-Hassan, Charitable and social activities 6. Paying zakat, charity, and granting Qard-e-Hassan 7. Zakat, charity, and benevolent funds 8. Zakat obligation, Qard fund	1	1	1	1	1	1	1	0	0	1	1	1	10	83

Table A1. *Cont.*

Broader Themes from Sustainability Indexes		Platonova, et al. [22]	Amran, et al. [56]	Aribi and Arun [57]	Mallin, et al. [12]	Aribi and Gao [58]	Farook, et al. [17]	Rahman, et al. [59]	Hassan and Harahap [15]	Othman and Thani [60]	Haniffa and Hudaib [61]	Maali, et al. [62]	Dusuki [63]	Frequency Distribution	Percentage
5. Product and Services	1. Products and services 2. Products 3. Products and services 4. Products, services, and fair dealing with supply chain 5. Products and services 6. Products 7. Products and services	1	1	0	1	1	0	1	1	1	1	0	0	8	67
6. Environment	1. Environment 2. Environment 3. Environment 4. Environment 5. Environment 6A. Energy and water conservation 6B. Waste recycling policies 6C. Financing companies not harming the environment 7. Environment	0	1	1	1	0	0	1	1	1	0	1	1	8	67
7. Mission and Vision	1. Mission and vision statement 2. Strategy—corporate vision 3. Vision and mission statement 4. Vision and mission statement	1	1	0	1	0	1	0	0	0	1	0	0	5	42
8. Customer and Clients	1. Ethical behavior, stakeholders' engagement, and customer relations 2. Listening to public view and concern, fostering Islamic values among customers 3. Customers 4. Late repayments and insolvent clients	0	0	0		1		0	1	1	0	0	1	4	33
9. Debtors	1. Commitment to debtors 2. Debtors 3. Debtors 4. Commitment to debtors	1	0	1	1	0	1	0	0	0	1	0	0	5	42
10. Other	1. Finance and Investment 2. Contribution	0	0	0		0			0	1	0	0	0	1	8

Table A2. Shortlisted Islamic indicators from broader sustainability themes used in the Islamic banking industry.

Broader Themes	Platonova, et al. [22]	Amran, et al. [56]	Aribi and Arun [57]	Mallin, et al. [12]	Aribi and Gao [58]	Farook, et al. [17]	Rahman, et al. [59]	Hassan and Harahap [15]	Othman and Thani [60]	Haniffa and Hudaib [61]	Maali, et al. [62]	Shortlisted Sustainability Indicators
1. Employees	Training: Shariah awareness	Training: Shariah awareness	The policy on education and training in relation to the Islamic financial institution	Employee training and development in line with Islamic principles	0	0	Training: Shariah awareness	1A. Religious freedom for Muslims to perform prayers. 1B. The proper place of worship for employees.	Training: Shariah awareness	The policy on education and training of employees in line with Islamic principles	Shariah education for the employee	1. Islamic training and education for the staff (8 indexes).
2. Community and Society	Conferences on Islamic economics and other educational areas	Zakat. Qard-e-Hassan and Sadaqah -for strategic social development.	0	Zakat	0	0	0	Scholarships. Sadaqah/Waqf/ Qard-e-Hassan.	Conferences on Islamic economics	0	Supporting charities and community projects	2. Sadaqah, charity, Qard-e-Hassan (4 indexes). 3. Offering scholarships, conducting Islamic conferences (3 indexes).
3. Governance/ Shariah Compliance	0	1A. Nature of unlawful transactions. 1B. Allocation of profits based on Shariah principles. 1C. Shariah screening of investments. 1D. Zakat. calculation and payment	1A. Nature of unlawful transactions. 1B. Compliance with Shariah in all products and services.	Commitment to ethical conduct	1A. Report of SSB. 1B. Nature of unlawful transactions or services.	1A. Unlawful haram transactions. 1B. Shariah supervisory council. 1C. Unusual supervisory restrictions.	1A. Nature of unlawful transactions. 1B. Allocation of profits based on Shariah principles. 1C. Shariah screening of investments. 1D. Zakat calculation and payment	Declaration of forbidden activities	SSB Report	Nature of unlawful transactions	Fostering Islamic values among staff	4. Disclosure of earnings prohibited by Shariah (7 indexes). 5. Shariah screening of investments (3 indexes). 6. Allocation of profits based on Shariah principles (3 indexes).
4. Zakat/Charity/ Qard-e-Hassan	Zakat, charity, and benevolent funds (Qard-e-Hassan)	Zakat, charity, and benevolent funds (Qard-e-Hassan)	Zakat, charity, and benevolent funds (Qard-e-Hassan)	Charity and zakat	Zakat, charity, and benevolent funds (Qard-e-Hassan)	Zakat, and (Qard-e-Hassan)	0	0	Zakat, charity, and benevolent funds (Qard-e-Hassan)	Zakat, charity, and benevolent funds (Qard-e-Hassan)	Zakat, charity, and benevolent funds (Qard-e-Hassan)	7. Zakat payment (9 indexes). 8. Charity/Sadaqah (8 indexes). 9. Qard-e-Hassan (benevolent funds) (8 indexes).

Table A2. *Cont.*

Broader Themes	Platonova, et al. [22]	Amran, et al. [56]	Aribi and Arun [57]	Mallin, et al. [12]	Aribi and Gao [58]	Farook, et al. [17]	Rahman, et al. [59]	Hassan and Harahap [15]	Othman and Thani [60]	Haniffa and Hudaib [61]	Maali, et al. [62]	Shortlisted Sustainability Indicators
5. Products and Services	1A. No involvement in non-permissible activities. 1B. Approval ex-ante by SSB for new product.	1A. Introduction of SSB-approved new product. 1B. Basis of Shariah concept on new products.	0	New product and services in maintenance with religious credentials	0	Products and services in line with Shariah principles	1A. Introduction of SSB-approved new product. 1B. Basis of Shariah concept on new products.	Halal status of the product	1A. Approval ex-ante by SSB for the new product. 1B. Basis of Shariah concept on new products	0	0	10. Approval of new products and services by the Shariah Committee (7 Indexes).
6. Environment	0	1. Introduction of green product. 2. Amount of donations to environmental awareness.	Lending policy	0	0	0	1. Introduction of green product. 2. Amount of donations to environmental awareness. 3. Investment in sustainable development projects.	Environmental education	0	1A. The amount and nature of any donations or activities undertaken to protect the environment. 1B. The projects financed by the bank that may lead to harming the environment.	Financing companies not harming the environment	11. Funding for organizations upholding a green environment (4 indexes). 12. Amount of donations to environmental awareness (3 indexes). 13. Introduction of green products and services (3 indexes).

Table A3. Four-step axial coding for categorizing sustainability indicators into three dimensions of sustainability.

Items	1: Phenomena	2: Causal Condition	3: Intervening Strategies	4: Consequences	Category
	Q1: How are the item and category related to each other?	*Q2: How do the item and category influence each other?*	*Q3: What are the actions and strategies required to relate item and category?*	*Q4: What are the consequences of relating item and category?*	
1. Shariah screening of investments	The item and category are related to each other through their economic kind of nature. The investments are made through the funds available to the Islamic banks in the form of different economic capitals. The investment of Islamic banks is recorded in the annual reports of the Islamic banks, which depicts the economic position of banks. Hence, based on the economic nature this item and category are closely related to each other.	The item and category greatly affect each other based on inductive information. This is because it will increase the trust of stakeholders in Islamic banks to be more in line with Islamic values by executing and reporting on this item. The increased trust of stakeholders would eventually lead the Islamic bank to raise more funds. This would gradually improve its economic viability. Thus the object and category favourably affect each other based on the positive causal situation.	The strategy adopted by this study to relate the item to economic sustainability is to establish its theoretical relation. Following the Maqasid al-Shariah principle, this study ponders that the investment screening of Shariah falls under the "essential" category and "preservation of faith and wealth" subcategory. Based on inductive knowledge and Islamic teachings, preservation of wealth according to Islamic teachings will improve economic sustainability. Hence, as a strategy and action, Islamic banks are required to intensify the level of Shariah screening of investments for better economic sustainability.	Based on inductive knowledge, relating item and category with each other will improve the economic sustainability profile of the Islamic banks. This will offer Islamic banks greater economic surveillance and better management of Islamic funds in compliance with Shariah principles.	**Economic Sustainability Dimension**
2. Allocation of profits based on Shariah principles	This item and category relate to each other based on their economic (monetary) nature. Profits are paid from the earnings of banks, recorded in the income statement. The income statement shows the economic condition of the banks. Hence, this item and category follow the same philosophy and are related to each other in monetary terms.	As per Islamic law, Islamic banks are expected to allocate profit to all depositors with complete fairness, and also to protect their capital in the process. The dedication of such actions would increase the customer's interest in the Islamic bank, which will increase deposits. It would thus boost the economic viability of Islamic banks. Thus the item and category favorably affect each other based on the causal situation.	This is based on the strategy of establishing a theoretical link between the item and category. The principles of Maqasid al-Shariah alludes to the allocation of profits based on Shariah principles falling under the "essential" category and "preservation of wealth" subcategory. Based on inductive knowledge, better wealth preservation will improve economic sustainability accordingly. Hence, the action and strategies required by Islamic banks are to further ensure the allocation of effective Shariah principles to safeguard economic sustainability.	As a consequence of relating this item with the category, it will safeguard the economic sustainability of Islamic banks. As a causal condition, following Shariah principles in profit sharing will positively address the stakeholders, which may increase the cash inflow as a positive goodwill of the banks. As a consequence, economic sustainability will be improved.	

Table A3. *Cont.*

3. Qard-e-Hassan	This item is related to the economic sustainability dimension because of its monetary nature. This is because Qard-e-Hassan is paid as an interest-free loan from the economic profit of banks. The bank with the most economic funding (profits) can distribute more Qard-e-Hassan and vice versa. Therefore, this item and category are related to each other in terms of the same segment of recording, i.e., financial statements.	The Qard-e-Hassan financing facility is more applicable in poor or underdeveloped countries where it can serve to remove hardship from society and life. Providing Qard-e-Hassan to poor customers will increase the goodwill of the Islamic banks not only in their customers' minds but also in public at large. As a result, Islamic banks will attract more deposits from other stakeholders, which may strengthen their economic sustainability positively. Hence, based on the causal condition the item and category positively influence each other.	According to the principles of Maqasid al-Shariah, this study categorized Qard-e-Hassan as a complementary item to the subcategories of preservation of self or life and preservation of posterity. This is based on inductive knowledge when the self, life, and posterity of people are preserved. The economic burden on them is reduced. Hence, to improve the economic sustainability of Islamic banks' stakeholders and the banks themselves, these principles can serve as a strategic base.	Linking Qard-e-Hassan with economic sustainability will improve economic sustainability. One would argue that paying interest-free loans should decrease economic sustainability in the short run. However, holistic inductive knowledge would argue that it will improve economic sustainability in the long run. This is because of the goodwill philosophy.	**Economic Sustainability Dimension**
4. Charity—Sadaqah—Waqf	The items of charity and economic sustainability are closely related to each other based on their monetary nature. Charity is paid from the different banking sources and funds, which comes under the economic head of the annual reports. Therefore, this item and category both share the same financial head under the annual report of the Islamic banks and are strongly related to each other.	In the context of Islamic banks, paying charity through Sadaqah and Waqf is a part of their operations. Islamic banks are required to channel the income derived from unclear or tainted activities to charitable bodies, including Waqf institutions. Circulating wealth to the people through charity, Sadaqah and Waqf have upgraded the image of Islamic banks and subsequently, improved their economic sustainability. Hence, based on the causal condition the item and category positively influence each other.	According to the principles of Maqasid al-Shariah, this study posits that the instrument of donating to charity through the Islamic instruments of Sadaqah and Waqf falls under the "embellishment" category. Paying charity through Sadaqah and Waqf is a part of their operations. Islamic banks are required to channel the income derived from unclear or tainted activities to charitable bodies, including Waqf institutions. Circulating wealth to the people through charity, Sadaqah, and Waqf has upgraded the image of Islamic banks and subsequently improved economic sustainability. Hence, as an efficient strategy and action, Islamic banks must channel charity to the least addressed SDGs to promote sustainable development, which as a consequent will improve their economic sustainability based on the goodwill and compliance philosophy.	The linkage of charity with the economic sustainability dimension will improve economic sustainability. In line with the philosophy of Qard-e-Hassan, in the short term charity payment decreases the profit of Islamic banks, which can be perceived as a negative impact on economic sustainability. However, in the long run, based on the goodwill philosophy, the instrument of charity payment will improve the economic sustainability of Islamic banks as a consequence of receiving more funds through their positive goodwill.	

Table A3. *Cont.*

5. Disclosure of earnings prohibited by Shariah	Based on Islamic philosophy the earning of income by prohibited sources is not allowed. Therefore, if any bank is willingly dealing in it and is not recording it, it can affect the economic condition of an Islamic bank negatively and vice versa. Hence, the progression of the economic performance of Islamic banks lies in avoiding haram profit. If it is committed mistakenly, the bank must immediately send it to charity. Hence, this item is strongly related to the economic sustainability dimension based on the Shariah philosophy.	To prevent the recurrence of such a transaction, Islamic banks must design control systems and forward any other gain to the funds of charities. This will strengthen the client's confidence in Islamic banks. More deposits will be produced with improved confidence, and more deposits will boost the economic viability of Islamic banks. Therefore the item and category positively affect each other based on the positive causal situation.	As a strategy, to develop the theoretical link between the item and category, based on the principles of Maqasid al-Shariah, this study posits that the disclosures of earnings prohibited by Shariah are complementary to the preservation of faith, self, and wealth. This is because in Islam all financial transactions must be transparent, accurate, and fully recorded. All income received from non-Shariah sources must be fully audited and managed, otherwise they would affect the economic sustainability of the Islamic bank. Hence, as a strategy and action, Islamic banks must properly channel these earnings to charity funds to preserve their economic sustainability.	The consequences of relating this item with economic sustainability may be seen in the shape of strong economic sustainability. This is because the recording of unlawful and haram income and simultaneously dispatching it to a charity fund will increase the Shariah rating process of Islamic banks, which as a consequent will keep the existing economic stakeholders satisfied, and will attract more customers, which will increase the economic sustainability of Islamic banks.	**Economic Sustainability Dimension**
6. Zakat payment	Using inductive knowledge, zakat is related to the economic category based on the fact that zakat is paid from the income earned and is reported on the economic part of the annual report, i.e., on the income statement. Hence, both are related to each other based on their financial nature.	Based on inductive knowledge, zakat item zakat and the economic category strongly influence each other, i.e., zakat payment increases the goodwill of Islamic banks. As an effect of high goodwill, the banks generate more funds, which eventually influence their economic sustainability positively.	The strategy adopted by this study to relate the item with the category is by developing a theoretical link. According to Maqasid al-Shariah, zakat falls under the subcategory of the preservation of wealth. As a strategic requirement, the principles assure a link in the presence of Shariah principles. Now as an action, the bank must channel its zakat payment to SDGs that are relatively unaddressed. As a result of such actions and compliance, the economic sustainability of Islamic banks will get better.	The consequences of relating zakat with the economic category are assumed to be positive. Based on the goodwill philosophy (causal condition), it improves the economic sustainability of Islamic banks. Strong economic sustainability ultimately improves the financial performance of Islamic banks in a positive way. Hence, consequently, the relative results are positive.	

Table A3. *Cont.*

7. Quota funding to organizations not harming a green environment	Islam considers humans the stewards of the earth. Based on this, every business that operates under Islamic principles must preserve the ecosystem. Therefore, based on the Shariah philosophy of stewardship, this funding is related to environmental sustainability.	The causal condition between this funding and environmental sustainability is significant. The low funding for organizations that are involved in renewable energy projects will lead to a lower level of green projects, which as a result will reduce environmental sustainability and vice versa. Hence, the causal condition between this item and category depends on the level of funds. If there are more funds, environmental sustainability will be better and vice versa.	Based on the theory of Maqasid al-Shariah, the above instrument is linked to the main category of "essential" and subcategory of preservation of posterity and preservation of life. Hence, it is assumed that there is a theoretical link between the item and category in the context of Shariah. The action required by Islamic banks is to prioritize funding for better environmental preservation.	The consequence of relating this funding with environmental sustainability will protect the environment. This is because that funding as a consequence will accelerate green projects, which will positively protect the environment.	
8. Amount of donations given to environmental awareness	This item also relates to the environmental sustainability dimension based on the Islamic philosophy of humans as stewards of the earth. This philosophy triggers the banks to distribute donations to environmental awareness. Hence, this item and category are related to each other based on the Islamic concept of stewardship.	The causal condition between the funding given for environmental awareness and the environmental sustainability dimension depends on the level of funds. If the amount of funds is high, the causal condition would be high. If the amount is less the causal condition would be negative.	According to the principles of Maqasid al-Shariah, this item is categorized as the preservation of self/life and the preservation of posterity under the main category of "essential" because there exists a theoretical link and consensus between this item and the principles of Shariah for improving environmental sustainability. Therefore, as a strategy and action, Islamic banks are required to increase the amount of such donations.	The consequence of relating these donations to environmental sustainability will protect the environment and will improve environmental sustainability ratings if the funding amount is high and vice versa.	**Environmental Sustainability Dimension**
9. Introduction of green products and services	The item and the category of environmental sustainability relate to each other based on the nature of service and product initiation. This is because the purpose of launching the product or service is to keep the environment in nature. Hence, based on the purpose, this item and category relate to each other.	The causal condition between this item and category is significant in terms of impact. The offered product and service would create a positive impact on the environment based on its purpose of serving the environment. Hence the causal condition is perceived as positive.	According to the theory of Maqasid al-Shariah, this item is categorized as the preservation of self/life and the preservation of posterity under the main category of "essential" because there exists a theoretical link and consensus between this item and the principles of Shariah for improving environmental sustainability. Therefore, as a strategy and action, Islamic banks are required to increase the production and services of green products.	The consequence of relating this item to environmental sustainability will bring positive environmental ratings. This is because those products and services as a consequence will accelerate green projects, which will protect the environment.	

Table A3. *Cont.*

10. Islamic training and education for staff	This item is related to the social sustainability dimension based on the nature of the work. That is, Islamic training and education for staff would ensure decent work practices ensured by Shariah. As Islam prohibits discrimination based on gender, race, or ethnicity, the concept is referred to as Husn-e-akhlaq/obligingness.	The causal condition between this item and category depends upon the standard of training and education. If the standard of Islamic education is in-depth and pure, it will boost the character of banking staff positively towards their co-workers, which as a cause will affect social sustainability positively.	Islamic training and education are categorized as a complimentary item to the preservation of intellect under the category of "essential." Based on the consensus and theoretical link between these items, Islamic banks as a strategy are required to set up a banking institution dedicated to supporting social justice and social up-gradation through banking staff.	The linking of Islamic training and education for staff with social sustainability as a consequence will bring positive outcomes in the social dimension of sustainability.	**Social Sustainability Dimension**
11. Scholarships	This is related to the social sustainability dimension because providing scholarships to multiple stakeholders will raise the quality of education in society and will uplift social standards as well.	The causal condition of this item with that of social sustainability is also perceived as positive. This is because providing scholarships will uplift the standard of education of different stakeholders, and those stakeholders using their knowledge and education may work for the betterment of society based on the social contract theory.	According to the theory of Maqasid al-Shariah, this item of scholarships is categorized as a complimentary item to the preservation of intellect under the main category of "essential" because there exists a theoretical link between this item and Shariah principles. So, as a way forward, Islamic banks must increase the amount of funding for scholarships to reduce child labor and forced labor. Eventually, it will improve the social sustainability of Islamic banks.	There are fears that due to the current turmoil of COVID-19, students from mostly underdeveloped or developing countries may completely lose out on their education. This can result in more child-labor cases. Therefore, this is the most appropriate time for Islamic banks to start offering more scholarships to peoples from mostly underdeveloped countries to avoid child-labor cases. Hence, the consequences of offering scholarships on social sustainability would be very positive.	

Table A3. *Cont.*

12. Product and service labeling (approved by the Shariah Committee)	This is related to social sustainability because Islam prohibits dealing in haram products and services. Muslims must preserve faith while doing business. Hence, based on the principles of Islamic faith, this item and category are related to each other.	The causal condition between this item and social sustainability is also perceived positively. This is because unethical labeling that can affect any people from any religion may cause high distress among the stakeholders of Islamic banks. Therefore, the causal condition between this item and category is significant.	According to the theory of Maqasid al-Shariah, the product and service approval from the Shariah Committee is categorized as essential under the subcategory of preservation of faith because there exists a theoretical link between this item and Shariah principles. So, as a way forward, as a strategy and action, Islamic banks are required to deepen the process of Shariah evaluation to safeguard its social sustainability.	Nowadays most banking services and products are provided online or using electronic machines that are directly associated with people and society. For instance, the content in the advertisements of Islamic banks must be ethically and socially acceptable for all stakeholders from all religions. Ignoring ethical elements in the delivery of products and services to society may directly affect the social sustainability of Islamic banks. Hence, the Shariah Committee must ensure the elements of society before approving any product or service. This is because the intended objectives of the principle of Shariah are to achieve socioeconomic justice for individuals and society and to enhance welfare in society. Hence, the consequence of this linkage is positive.	**Social Sustainability Dimension**

Table A4. Four steps of axial coding for aligning sustainability indicators with the UN SDGs.

Items	1: Phenomena	2: Causal Condition	3: Intervening Strategies	4: Consequences	Alignment with the UN SDGs
	Q1: How are the item and category related to each other?	*Q2: How do the item and category influence each other?*	*Q3: What are the actions and strategies required to relate item and category?*	*Q4: What are the consequences of relating item and category?*	
1. Shariah screening of investments	The item and UN SDG are related to each other based on the principles of transparency. Shariah screening of investments offers great transparency and accountability based on Islamic laws in developing effective institutions. Shariah objectives aim to promote social welfare (Al-Maslahah), therefore, the instrument of Shariah screening of investments will ensure the prevention of investments in inappropriate haram business (forbidden by Islamic laws) such as gambling, which generally violates the business objectives of free and fair exchange, which halts the process of building strong and transparent institutions.	The causal condition between the sustainability indicators and UN SDG 6 and sub-goal 16.6 is considered positive. This is because Shariah objectives aim at achieving socio-economic development.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDG will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDG 16 (sub-goal 16.6)
2. Allocation of profits based on Shariah principles	The item and UN SDG are related to each other in terms of principles and laws, as UN SDG 10.3 alludes to reducing inequality of outcomes by eradicating discriminatory principles and laws. On the other hand, Shariah principles (based on the principles of socio-economic justice) reduce inequalities of outcomes by fairly distributing profit to all stakeholders.	The causal condition between the item and SDG is considered positive. This is because the allocation of profits based on Shariah principles will enhance compliance of Islamic banks with SDG goal 10 and its sub-goal 10.3.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDG will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDG 10 (sub-goal 10.3)

Table A4. *Cont.*

3. Qard-e-Hassan	The item and UN SDGs are related to each other in terms of their philanthropic nature and addressing the needs of poor stakeholders. This study relates the instrument with multiple SDGs because these goals are interconnected. Improvement in one goal, for instance no poverty, as a subset, will bring an improvement in the other goals as well, such as alleviating poverty enhancing the purchasing power of stakeholders, which allows them to afford food, health services, water, and energy.	The causal condition between the item and multiple SDGs is perceived as positive. This is because the item will address the needs of various deprived stakeholders related to SDGs 1, 2, 3, 4, 6, 7, 10, and 15, which as a result will reduce the challenges faced by those deprived stakeholders.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDGs will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDGs 1, 2, 3, 4, 6, 7, 10, 15
4. Charity—Sadaqah—Waqf	The item and UN SDGs are related to each other in terms of their philanthropic nature and addressing the needs of poor stakeholders. Charity (Sadaqah and Waqf) are used for poverty alleviation and socioeconomic development. In line with that, this study related the instrument with UN SDGs 1, 2, 3, and 4. This is because these goals are directly related to poverty alleviation and socioeconomic development.	The causal condition between the item and UN SDGs is perceived as positive. This is because channeling charity towards the goals will address the needs of the deprived stakeholders.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDGs will increase, which will promote sustainable development and will mitigate the stress fromCOVID-19 on the triple bottom line.	SDGs 1, 2, 3, 4
5. Disclosure of earnings prohibited by Shariah	The item and UN SDG are related to each other based on the principles of transparency. UN SDG 16.5 alludes to building transparent, accountable, and effective institutions at all levels. The earnings are channeled by Islamic banks to charity funds because they violates the principles of Islamic business. Dispatching the earned amount from the profit of Islamic banks ensures greater transparency, accountability, and business effectiveness as well. Consonant with that, this study relates the instrument to UN SDG 16 and 16.5.	The causal condition between the item and UN SDG is also significantly positive. This is because disclosures of earnings prohibited by Shariah will ensure business transparency, which helps build a strong institution.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDG will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDG 16 (Sub-goal: 16.6)

Table A4. *Cont.*

6. Zakat payment	The item and UN SDGs are related to each other in terms of their philanthropic nature and addressing the needs of poor stakeholders. Zakat is paid with the aim of supporting disadvantaged people in society (Malik, 2016). In the same vein, this study relates the instrument of zakat to the UN SDGs because these goals are directly related to the needs of disadvantaged people.	The causal condition between the item and UN SDGs is also perceived as positive. This is because channeling zakat towards the goals will address the needs of the deprived stakeholders.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDGs will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDGs 1,2,3,4,6,7,10,15
7. Funding organizations not harming a green environment	This instrument and the UN SDGs are related to each other based on the principles of protecting the environment.	This instrument and the UN SDGs positively affect each other. Increase in this instrument will bring positive outcomes to the SDGs. Hence, the causal condition is perceived as positive.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDGs will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDGs 7,13,14,15
8. Amount of donations given for environmental awareness	This instrument and the UN SDGs are related to each other based on the principles of protecting the environment.	This instrument and the UN SDGs positively affect each other. Increase in this instrument will bring positive outcomes to the SDGs. Hence, the causal condition is perceived as positive.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDGs will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDGs 7,13,14,15

Table A4. *Cont.*

9. Introduction of green products and services	This instrument and the UN SDGs are related to each other based on the principles of protecting the environment.	This instrument and the UN SDGs positively affect each other. Increase in this instrument will bring positive outcomes to the SDGs. Hence, the causal condition is perceived as positive.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDGs will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDGs 7,13,14,15
10. Islamic training and education for staff	This instrument and UN SDG are related to each other in terms of the category of education.	The causal condition between the instrument and the UN SDG is perceived as positive. The training will serve UN SDG 4 and 4.7 positively.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDG will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDG 4 (Sub-goal: 4.7)
11. Scholarships	This instrument and UN SDG are related to each other in terms of the category of education	The causal condition between the instrument and the UN SDG is perceived as positive. The training will serve UN SDG 4 and 4.7 positively.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDG will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDG 4 (Sub-goal: 4B)
12. Product and service labeling (approved by the Shariah Committee)	This instrument and category are related to each other in terms of product and service responsibility aimed at society. As such Shariah approval will promote responsible production and consumption.	The causal condition between the item and UN SDG is positive. Shariah approval will promote responsible consumption and production. Hence, it will support UN SDG 12 positively.	As a strategic requirement, this study proposes a modern governance role, i.e., SDG governance (refer to Figure 7). The modern governance role ensures the alignment process between sustainability indicators and the UN SDGs in four detailed stages.	As a consequence of relating the item and category, the compliance of Islamic banks with the SDG will increase, which will promote sustainable development and will mitigate the stress from COVID-19 on the triple bottom line.	SDG 12

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