sustainability

MDPI

Article

A Qualitative Study of Legacy Systems Modernisation for Citizen-Centric Digital Government

Humairath Abu Bakar *, Rozilawati Razali and Dian Indrayani Jambari

Research Center for Software Technology and Management, Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia (UKM), Bangi 43600, Selangor, Malaysia
* Correspondence: humairath@gmail.com

Abstract: Legacy systems are valuable assets in most public sector agencies that have been in use for a long time. These systems support government service delivery to the citizens and maintain vital public administration functions and data. However, legacy systems are often related to technical difficulties that impede innovation efforts. The maintenance of the systems has become challenging and incompatible with the demands of digital transformation in the public sector. Due to their importance, the systems cannot be easily discarded. Rebuilding the old systems from scratch entails a long development timeline, high cost, and the loss of critical service functionalities. These circumstances encourage the public sector agencies to implement the modernisation of legacy systems. However, the modernisation effort for legacy systems in the public sector is not straightforward. Besides technical aspects, it should also consider non-technical aspects, including the requirements of the new era of citizen-centric digital government. In order to achieve this aspiration, a complete strategy must be developed to serve as a guide for government agencies. Hence, the purpose of this study is to develop a comprehensive guideline for the public sector. The research has been developed using a qualitative methodology that incorporates the theoretical and empirical phases. The theoretical phase was conducted through a literature review of previous studies related to the research topic. The empirical phase in the public sector was implemented and analysed using phenomenology and grounded theory methods. A total of 19 informants were involved in the individual and focus group interviews conducted. The study results revealed that human, process, product, and organisation aspects as well as the related characteristics of the citizen-centric influence the legacy systems modernisation in the era of digital government. The findings contribute as a complete guideline for the public sector agencies in modernising the legacy systems in line with the citizen-centric digital government vision.

Keywords: legacy system; legacy system modernisation; legacy system migration; digital government; citizen-centric

Citation: Abu Bakar, H.; Razali, R.; Jambari, D.I. A Qualitative Study of Legacy Systems Modernisation for Citizen-Centric Digital Government. *Sustainability* **2022**, *14*, 10951. https://doi.org/10.3390/su141710951

Academic Editors: Miltiadis D. Lytras, Anna Visvizi and Anastasija Nikiforova

Received: 23 July 2022
Accepted: 25 August 2022
Published: 2 September 2022

1. Introduction

Many organisations including the public sector continue to rely on their old information systems, referred to as legacy systems. Legacy systems are core systems and important assets to organisations [1–3]. They are essential as they have been in use for a long time and possess high business value. However, organisations that are still using these old information systems, are exposed to the risk of system failure. Legacy systems are frequently associated with technical concerns, difficult to be maintained or replaced [4–6]. Due to the importance and great reliance on the systems, they cannot be stopped, even if they are unable to offer the necessary services in line with the current needs [2]. Organisations would face higher risks if they decided to replace their legacy systems with new information systems. These include higher expenses, a longer time frame as the systems need to be redeveloped from scratch, and the risk of losing critical functions [7–9]. Because of these reasons, many organisations are now opting for legacy systems modernisation to ensure that these systems remain relevant in offering services to the citizens [10–12].

The use of legacy systems in the public sector is also increasingly challenging and unable to support the service delivery to the citizens. The government's digitalisation initiatives are hampered by the presence of legacy systems [13,14]. The rapid advancement of technology has rendered legacy systems to become obsolete and out of step with the digital transformation towards the era of industrial revolution 4.0 [15]. Besides the manufacturing industry, the fourth industrial revolution also impacts ICT, education and labour supply [16–18]. It is related to data integration, smart features, and the globalisation of data usage to reach the predicted future benefits. Traditional business practices that are supplanted by modern technology have a greater chance of remaining relevant and successful in the long run [19]. Therefore, the public sector agencies that are still relying on legacy systems for their daily operations need to think about the system's capability and modernise the systems in fulfilling the government's aspirations in line with the new era.

Legacy systems modernisation is a multi-faceted task that includes not just technical but also business, environmental, and organisational aspects [20–22]. In the public sector, legacy systems are involved in complicated information interactions, organisational culture, and normative settings in the public sector [21]. Furthermore, the requirements of the citizens, who are the primary users of government services, must be prioritised [23,24]. The initiative toward citizen-centric digital government is a government's endeavour to increase the use of technology in providing excellent services to citizens. In line with this initiative, the service delivery systems developed need to embrace a new citizen-centric design that is more interactive and involves the citizens [25,26].

Previous scholars have established several models and methods to help in the implementation of legacy systems modernisation [27–29]. However, the aspects involved were studied separately and were not comprehensive. Most of the studies suggested strategies and methods as well as implementation processes from a technical perspective [29,30]. They were also not specialised in the public sector and do not emphasise the importance of a citizen-centric digital government transition.

The above statements indicate the necessity for a comprehensive guideline that is capable of driving the implementation of legacy systems modernisation in the public sector. Therefore, this research was carried out to discover the factors that must be considered while undertaking legacy system modernisation. The objective of this study is to identify the factors and elements involved in legacy systems modernisation for a citizen-centric digital government. This study takes into account both technical and non-technical aspects. These aspects include people, process, organisation, and product involving related factors and elements. The findings are in line with the current needs of citizen-centric digital government and the product quality criteria in providing the best service to the citizens.

This study produces comprehensive guidelines for implementing legacy systems modernisation for citizen-centric digital government. The results of these findings are expected to help the government in formulating more effective development programs toward legacy systems modernisation. In addition, the discovery of new factors in this study has further expanded the literature in the field of information systems and software engineering.

This paper is structured as follows. Section 2 discusses the literature review leading to the discovery of related factors in the implementation of legacy systems modernisation for citizen-centric digital government. This is followed by Section 3 which discusses the methodology employed in the study. Section 4 reports the findings of the study. The final section concludes the paper and outlines the limitations of the study.

2. Literature Review

The world is currently transitioning to the fourth industrial revolution, which features advanced technologies. The fourth industrial revolution that is closely related to smart features, the globalisation of data usage, and information integration to achieve expected future advantages has begun to attract researchers' attention in recent literature [31–33]. Organisations can profit from the transition to the new revolution in a number of ways including by improving organisational competitiveness and increasing flexibility and

productivity through the use of modern technology [34,35]. Along with the development of technology worldwide, governments keep looking for innovative ways to serve the citizens. Governments are aiming for public sector transformation in line with global advancements. In this context, implementing the digital government is intended to focus more on utilising cutting-edge technology in enhancing the service provided to citizens [36]. Along with that, the government needs to think about the capability and direction of the legacy systems to make sure they remain relevant to the latest needs.

2.1. The Modernisation of Legacy Systems for Citizen-Centric Digital Government

Agencies in the public sector that are still using old systems will confront challenges. Despite the fact that these systems lead to technical issues, they cannot be easily abandoned since they hold critical public administration data since they started operation [4,5]. However, if they continue to use legacy systems, they will have to deal with the technical issues, as well as the high cost and impediments to innovation for the digital government implementation [8,13]. At the same time, the replacement of legacy systems is vulnerable to risk, and it is feared that the new system would not be able to support business as effectively as legacy systems [8]. As such, legacy systems modernisation should be an option for the public sector that can no longer maintain the systems.

Modernisation is the process of enhancing legacy systems beyond what can be done during the maintenance period by employing proper approaches. Modernisation improves existing systems to enable them to communicate with the latest technology and respond quickly to business changes [4,37]. Several aspects need to be considered when performing legacy systems modernisation. Modernisation encompasses not just the technological but also the business, organisational, and environmental aspects [8,21,27]. To carry out the government's directive, the new delivery system must include citizen-centric characteristics, including simple to use, more interactive, and involving the citizens [23,25,38]. All of these aspects must be taken into account to ensure the success of modernisation in improving service delivery to citizens.

2.2. The Factors Contributing to the Success of Legacy Systems Modernisation

As a guide to undertaking legacy system modernisation, several methodologies and models have been established by previous researchers. These studies indicated essential factors that contribute to the success of legacy systems modernisation for citizen-centric digital government. All the factors obtained were combined and arranged into related aspects to provide a holistic guideline. The technical and non-technical aspects include the process, people, product, and organisation.

2.2.1. Modernisation Process

The modernisation of legacy systems involves several steps and activities in related phases. Before implementing the technical processes of the modernisation, pre-implementation activities involving project requirements planning are important to be executed. Every legacy systems modernisation project requires detailed project planning [6]. This includes the scope and the cost of the project, time frame, human resources involved, and selection of appropriate modernisation techniques [5,27,39].

To get complete and up-to-date requirements for the modernisation of legacy systems, old and new requirements must be collected. The old requirements were obtained by implementing activities based on the reverse engineering approach [39,40]. The key factors involved in the reverse engineering approach are system understanding and requirements extraction. The understanding of the systems mainly is on the architecture of the systems, including the system functions, data, and constraints [27,39,41]. Requirements are then extracted consisting of business rules, logic, and data before being documented as a legacy system requirements specification [8,39,42].

The determination of new requirements is based on the requirements engineering process [42]. Requirements engineering is an essential activity for any information system

development, including legacy systems modernisation. Activities involved in this phase are the collection of requirements, analysis, specification preparation, and validation by users. The collection process is carried out with the relevant stakeholders using suitable methods [8,41]. The old and new requirements need to be analysed, and only the relevant ones should be documented [8,21].

The agreed system requirements are then designed for the new interface, database, integration and architecture [8,27,41]. It is then developed using the technique and programming language that was planned.

The modernised system needs to be tested according to the prescribed test type [8,27,39]. It should adhere to the test scripts, and legacy systems use cases [8]. However, testing based on the use cases involved more effort as it needs to be compared between legacy systems and modernised systems [7]. Therefore, the project implementation time frame needs to be planned well.

The system that has been tested can be implemented in a production environment. The installation involves hardware, software, and data migration. The system should be verified and monitored for some time for any failures or corrections [27]. Training to users and technical staff can be provided in parallel [39].

Citizen-centric digital government delivers services by focusing on the needs of the citizens. They are the end-users and service recipients of government services. In addition, service providers in the public sector agencies need to play their roles in ensuring the process runs smoothly in line with the digital government initiatives. They need to ensure the involvement of the citizens throughout the system development life cycle of legacy systems modernisation. This is important to make certain their needs will be taken into account [43,44]. Citizen involvement will improve the performance of the service delivery because there will be a better alignment between the government system and the work practices of the citizens [23]. Their involvement is needed according to the relevant modernisation phases [44,45]. To ensure the involvement of the citizens runs properly with good cooperation and collaboration from the people, awareness sessions should also be given [46]. The involvement can be implemented using relevant communication methods, including social media, which are now becoming one of the important channels [46,47].

2.2.2. People Involved

The successful modernisation of legacy systems requires the serious involvement of the service providers in the public sector agencies. This includes the business and technical representatives of the agency [41]. The project team consists of business experts, legacy system experts, and system developers, led by the project manager [1,41]. In addition, a testing team is also required to ensure quality testing [1,8]. The team must have technical skills, knowledge, and experience to ensure the process runs smoothly [37,41,48]. Good communication, relationships, and attitude are also important factors in the success of the project [1,49,50]. In addition, the support of the top management and the leadership of project managers are also the success factor of digital government initiatives [50,51].

In addition to the service provider involvement, in line with the needs of the digital government, citizens as the service recipient need to be involved as well [52]. For the citizens, ICT skills will impact their involvement [51,53]. This is because citizens come from various categories and backgrounds, and their levels of ICT skills are different.

2.2.3. The Organisational Environment

In the implementation of legacy systems, the organisational environment factors need to be determined. Although the challenges of modernising legacy systems are more focused on technical challenges, cultural, and business process challenges are more significant in the public sector [21]. The current work culture of public sector agencies will also influence the implementation of modernisation [48]. Besides, the modernisation of legacy systems needs to be in line with the direction and strategy of the business as well as the related policies [21,27,39]. It also depends on the availability of resources, including financial

allocation, implementing teams, and infrastructure [48,53]. Resistance to change is also one of the challenges in the implementation of new initiatives, including the modernisation of legacy systems in the public sector [21].

2.2.4. Product Quality and Characteristics

The government focuses on services that can enhance public value as part of its transformation to a citizen-centric digital government. Public value includes products or services that meet the expectation of the citizens, service efficiency, and methods that are innovative and flexible in taking into account the demands of the citizens [54]. To establish a sustainable citizen-centric digital government, the modernised legacy systems must ensure the citizens obtain the highest value from the best quality services provided [46]. To achieve that, the characteristics relating to the quality of the product must also be considered.

This study has considered four established methods and models in order to meet the overall quality characteristics, namely the Systems and Software Quality Model (ISO/IEC 25010:2011) [55], Data Quality Model (ISO/IEC 25012:2008) [56], Renaissance Method [57] and the SERVQUAL Model [58]. The characteristics were combined with the specific features of citizen-centric digital that have been discussed in relevant previous studies [44,59,60] The combination of these models and methods has resulted in comprehensive features encompassing product, data, and service elements. All relevant elements have been arranged according to three main factors, namely system quality, data quality, and service quality. System quality included functionality, performance efficiency, usability, compatibility, reliability, security, maintainability, and portability. Data quality took into account accuracy, completeness, up-to-date, compliance, and openness. Service quality included elements of effectiveness, efficiency, satisfaction, responsiveness, and transparency. A detailed explanation of the selection of models and methods can be found in [61].

From the literature reviews, few studies have developed several methods and models as guidelines for implementing legacy systems modernisation. The activities involved were explained technically. There were also few studies that described in general the non-technical processes involved such as planning and the project teams involved. As for the characteristics and requirements of citizen-centric digital government, this study has combined the citizen-centric characteristics that have been obtained with four models and methods that illuminate the general quality characteristics of a service product. All the initial factors and elements obtained will be combined and arranged accordingly with the findings from the empirical studies in producing a holistic guideline for the public sector.

3. Research Methodology

The research adopted a qualitative methodology of the study. The method enables researchers to gain better insight and knowledge of the study [62]. This study was carried out to identify the factors of legacy systems modernisation for citizen-centric digital government. The factors were gathered from the theoretical and empirical studies.

This study aims to answer the following research questions:

R1: What are the factors involved in legacy systems modernisation for a citizen-centric digital government?
R2: What are the elements for each of these factors?

The research design is illustrated in Figure 1.

This study involved three main phases namely theoretical study, empirical study A and empirical study B. The theoretical study was carried out through a literature review from documents identified related to the field of study. Empirical study A was implemented through data collection and analysis using the phenomenology research method. Next, the data collection and analysis for empirical study B were carried out using the grounded theory method. The output for all the phases is the factors and elements contributing to legacy systems modernisation for citizen-centric digital government.

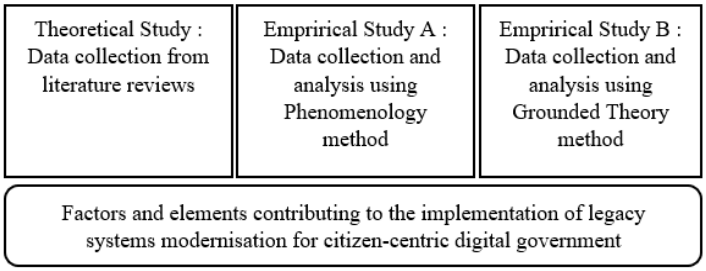

Figure 1. Research Design.

3.1. Theoretical Study

This study was carried out by analysing the previous studies on the research topic. The theoretical study reviewed documents including books, journal articles, proceedings, and reports. The search was performed from multiple online databases including Web of Science, Scopus, Springer, Elsevier and IEEE Xplore.

3.2. Empirical Study A

The first empirical study was carried out using the phenomenology research method. Phenomenology is a method in which data collection is carried out to obtain a person's lived experience of a concept or phenomenon [62,63]. The phenomenology method was used to identify factors related to legacy systems modernisation through a deep understanding of the informants' daily and actual experiences. This includes their experience in implementing the maintenance, modernisation, and redevelopment of public sector legacy systems.

There are two types of approaches in the study of phenomenological methods, namely hermeneutic phenomenology and transcendental phenomenology. Hermeneutic phenomenology is an approach that is oriented to the informant's actual experience and bracketing the researcher's experience [63]. Like other qualitative methods, it also involves the interpretation of the experiences to related themes of the research topic [63,64]. Hermeneutics involves the art of understanding an individual's actual experience until the implicit meaning behind it can be fully understood [65].

On the other hand, the transcendental phenomenology approach is less focused on the researcher's interpretation than hermeneutic phenomenology. Researchers in transcendental phenomenology will set aside their knowledge and experience regarding the phenomena under study and describe all the individual's experience fresh as the first time it was acquired [64].

This study employed the hermeneutic phenomenological approach. In addition to gaining the actual experience of the informants, it needs to be clarified and interpreted in accordance with the needs of the study. Interpretations and descriptions of actual experiences are made according to the themes and factors related to the modernisation of the legacy systems for citizen-centric digital government. Moreover, in the limited use of phenomenology research method in the field of information systems, it was found that the hermeneutic approach has been used effectively in several studies [66,67].

3.2.1. Sampling

Empirical study A adopted a purposive sampling technique where the sample is selected based on the ability of the informants to answer the research questions [62]. For the number of samples, data from only a few people who experienced the phenomenon and can provide details of their experience are well enough to explain the phenomenon study. No specific count of the sample was specified for the phenomenology method, but the recommended sample is from 1 to 10 people [68]. Therefore, the individual interviews for empirical study A were conducted with five selected informants who met the criteria that have been set.

The purpose of setting criteria was to ensure that the data obtained were in line with the needs of the study. The selection of informants was made based on the criteria of experience and knowledge of informants in the field of study. These highly experienced informants were chosen because they have real experience with the public sector legacy systems. They are also from the management level officers who have led several projects, including the modernisation of legacy systems and projects directly involved with the citizens. These criteria allow informants to narrate their experiences according to the needs of the study. The profiles of the informants are shown in Table 1.

Table 1. Informants' Profiles for Empirical Study A.

Informant Code	Agency	Position	Experience (Year)	Service Sector
INF 1	A	Deputy Director	29	ICT Consultation
INF 2	B	Senior Assistant Director	30	International Trade
INF 3	A	Deputy Director	26	Digital Government
INF 4	C	Deputy Director	31	Public Service
INF 5	D	Senior Assistant Director	34	Public Election

3.2.2. Instrument

Empirical study A was carried out through semi-structured interviews. This type of interview allows discussion to be made more interactive in gaining the informants' actual experience in depth. The instrument used in the sessions consists of general and open-ended questions [64]. The use of open-ended questions allows the researcher not to be influenced by their own experience and to get fresh answers from the informant's actual experience [62,64].

3.2.3. Data Analysis

In the phenomenological research method, data analysis more accurately refers to the process of breaking down, interpreting, and clarifying data without distorting the overall context of the phenomenon under study [64,69,70]. Using the full transcript of the audio recording that has been made, the following processes were performed:

- Preliminary listing and collection—All feedback related to the informant's experience on the modernisation of the legacy system and citizen-centric digital government were listed and collected.
- Reduction and deletion—All feedback was explored, and the audio recordings were listened to repeatedly for further understanding. Only relevant and necessary feedback for the study was taken into account. Overlapping, repetitive, and unclear feedback was eliminated or combined to obtain a more accurate and comprehensive description. This was required when the descriptions obtained from the informants were too long and need to be addressed holistically.
- Collection by themes—Next, some meanings or themes were created in describing the feedback. These themes were interpreted based on the research topics without changing the original meaning that had been obtained during the empirical study.
- Individual text descriptions—Structured text descriptions for each informant about their experiences according to the theme were prepared.
- Composite text description—From the individual text descriptions, a composite description representing the group as a whole was provided. It combined the experiences of all informants according to the themes related to the phenomena studied. The descriptions were also combined with the views of the researcher in giving a complete picture of the field studied [71].

3.3. Empirical Study B

Empirical study B was also carried out using a qualitative research method grounded theory. This method was widely used in various fields, including information systems [72–74].

Researchers can explore a process, activity, or event in-depth with information and generate or abstract the process based on those interactions [75]. This research method allows theories to be developed by identifying and analysing themes and categories and the relationships between them [76].

This method was used in empirical study B to identify factors related to the topic through the knowledge or experience of informants in the development, modernisation, or maintenance of government information systems, including legacy systems. Data collection for empirical study B was done through individual and focus groups with selected public sector agency informants.

3.3.1. Theoretical Sampling

Grounded theory sampling strategy refers to theoretical sampling techniques. Theoretical sampling was described as a sample determination based on subsequent data requirements [77]. Findings related to the theoretical concepts that have been developed will lead to the selection of appropriate informants. It is selected according to the need and not randomly or a sample that is representative of a group [72,78].

This empirical study B used a theoretical sampling technique that involved the informants based on different experiences in exploring various dimensions of the study. Appropriate informants were determined throughout the analysis and development phase of the concepts and factors.

Although it was difficult to predict the number of samples required, the suggested number is between 10 to 60 people depending on the adequacy and saturation of the information obtained [68]. In meeting the requirements of the developed theory, the sample size for the empirical study B was 14 informants who were categorised as experts based on the research need. The profiles of the informants are shown in Table 2.

Table 2. Informants' Profiles for Empirical Study B.

Informant Code	Agency	Position	Experience (Year)	Service Sector
INF 6	A	IT Officer	16	Accounting
INF 7	B	Principal Assistant Director	21	Public Service
INF 8	C	IT Officer	16	Public election
INF 9	D	Senior IT Officer	17	Education
INF 10	D	Senior IT Officer	17	Education
INF 11	D	Senior IT Officer	17	Education
INF 12	E	Principal Assistant Director	20	ICT Strategy and Architecture
INF 13	F	Principal Assistant Director	20	System Development
INF 14	G	Principal Assistant Director	22	Digital Government
INF 15	E	Senior IT Officer	16	ICT Strategy and Architecture
INF 16	A	Senior IT Officer	18	Accounting
INF 17	H	Director	20	Agriculture
INF 18	I	Senior IT Officer	17	Health
INF 19	E	Principal Assistant Director	21	ICT Strategy and Architecture

3.3.2. Instrument

Empirical study B was conducted through semi-structured interviews, which proved to be effective for all qualitative research methods [68]. The interview technique allows the researcher to ask not only the questions that have been prepared but also more flexible to change the questions according to the suitability of the situation during the interview process [79].

Individual and focus group interviews of empirical study B used interview questions as instruments. Questions consist of open-ended and more structured questions in the form of a process to obtain answers needed by the research question [65].

3.3.3. Memo Writing

In grounded theory research, memo writing is an important activity that needs to be implemented to ensure quality research methods throughout the research process [78,79]. The memo notes are more inclined to interpretive and theory-related notes. They are very useful that can make a quick overview of the idea as well as the coding and themes that existed [80]. Memo writing allows researchers to record the progress of research and analysis as well as record views and feelings about the data collected [73]. This is important in determining the direction of the data and helpful in determining the theoretical sampling of the study [80].

In empirical study B, memo notes were made for each interview session. This was to ensure that the important facts obtained from each informant, the strength of each session, and the information that was still lacking in the sessions were recorded. They were used as a reference for data collection planning for the next session.

3.3.4. Simultaneous Data Generation and Analysis

Another important feature that distinguishes the grounded theory research method from other methods in qualitative research is the implementation of data collection, analysis, and theory generation that occur simultaneously [73,80]. This means that after completing the data collection with each informant, the analysis should be done immediately before the next data collection. In implementing this simultaneous data collection and analysis process, a continuous comparative analysis was also done throughout the data collection sessions. Comparisons were performed among the incidents, codes, and categories until they were all fully integrated [73,81].

3.3.5. Open Coding

Open coding or initial coding is the first step in the data analysis of the grounded theory research method. Open coding is the process of examining data, generally line by line or word by word, before assigning open code to the data set [81]. It is a technique for identifying concepts collected in sub-categories and then into general categories from the data that has been collected and transcribed [82].

In the open coding data analysis for this empirical study B, the first step taken was to examine line by line the informants' feedbacks that were transcribed. Then, the keywords that described the field of study were determined and given the appropriate code. These concepts were combined in the related categories. The same steps were performed each time another informant's data was analysed.

3.3.6. Axial Coding

The next process of coding in the grounded theory research method is axial coding. It refers to the process of linking categories together through related subcategories [83]. It is called an axial because the coding takes place around the "axis" of the category and connects it to one dimension that describes the same properties. Open and axial coding are related and implemented simultaneously. The subcategories of open codings in empirical study B were combined and linked into related categories. This process aggregated all open codes into higher groups.

3.3.7. Selective Coding

The final coding phase in data analysis using grounded theory is selective coding. It is the process of integrating categories and refining theory [83]. Selective coding is an identification of the core codes that serve as a hub in building relationships between the acquired categories [73,84]. The data collection and selective analysis will continue until it reaches theoretical saturation to adequately describe and integrate all the categories into core categories [72].

In this study, all the sub-categories and categories identified for the modernisation of the citizen-centric legacy system were grouped and linked into several core categories. The

core categories that have been identified were people involved, modernisation processes, organisational environment, and citizen-centric products.

4. Results and Discussion

This study was carried out by first analysing the literature reviews of the research topic to get an initial idea of the topic studied. Then, empirical study A was conducted to identify factors related to legacy systems modernisation through the real experience of 5 informants from the public sector agencies. The data collection and analysis were implemented using the phenomenology method. Empirical study B was carried out using grounded theory with 14 informants who are knowledgeable in the area to understand the process of legacy systems modernisation for citizen-centric digital government in detail. It also aims in developing theories related to the study.

All the data obtained through these different phases are important and necessary in gaining a comprehensive and detailed understanding. Therefore, it was integrated by combining, comparing, and linking in giving a complete explanation of the problem studied. This process was implemented based on four aspects, namely people, process, organisation, and product. The following sections explained the results of the integration.

4.1. People Aspect

In the modernisation of legacy systems for citizen-centric digital government, the citizens' involvement includes the implementers from the internal public sector agencies and also the public as the end-users. The involvement of implementers is important as they are the ones responsible for developing and implementing the modernisation of legacy systems. They consist of the top management, project manager, project team, and testing team as stated in the theoretical study mentioned in both empirical studies. However, informants in empirical study B highlighted the importance of involving the project director. This is according to the current scenario of most agencies implementing modernisation projects, as each division is headed by a divisional director who is responsible for all the initiatives of the division. They need to have good leadership and network with top management for the benefit of the project.

For the top management, besides giving full support to the project, they need to have citizen soul and digital mindset characteristics in ensuring the success of the citizen-centric legacy systems modernisation. A digital mindset is important as a driver for smooth project implementation and direction. With the citizen's soul character, the top management will be able to empathise with the problems faced by the citizens, increasing the confidence of the citizens in the public service delivery system.

For the team members, including the project team and testing team, empirical study B stated the need for a new element of certification to be owned by certain members so that the relevant processes are implemented according to the set standards. Besides that, the elements of relationship and communication derived from the theoretical study initially were also mentioned in the empirical study B. However, the latter part of the informants disagreed and stated a more accurate element which is a soft skill in line with the need for citizen-centric services. In addition to technical skills, team members should have soft skills characteristics. It is a generic skill or strength that crosses a variety of criteria covering personality and group work. A person must possess this characteristic to maintain good relationships and interactions, including with the citizens.

Besides having ICT skills, as mentioned in the theoretical study, the public also needs to be willing to involve. According to empirical study B, the element of willingness from the citizens influences their involvement in the modernisation implemented.

4.2. Process Aspect

In implementing the process of modernising the legacy systems for citizen-centric digital government, clear and detailed explanations were obtained from all informants. A combination of experts in operating legacy systems as well as knowledge in implement-

ing information systems that involve the citizen has been able to explain the processes and best practices implemented. This has complemented the shortcomings not obtained during the theoretical study.

The modernisation process described by the informants was based on the System Development Life Cycle (SDLC) phases, in line with the findings from the theoretical study. Each phase involves activities and important elements that need to be taken into account to ensure the smooth running of the process.

4.2.1. Planning

The literature reviews stated the need to plan project requirements for the planning phase, including timeline, project cost, human resources, scope, and modernisation technique. There were also mentioned in both empirical studies. As noted in the theoretical study, organisational aspects influence the implementation of citizen-centric legacy systems modernisation projects. However, the activities and matters involved were not described in detail. From the interviews with the informants, elements related to the organisation need to be determined during the planning phase. The important elements were the business strategies and policy that affect the overall implementation of modernisation and need to be determined early. In preparing business strategies, enterprise architecture is a new emphasis for all agencies that need to be taken into account in order to facilitate a comprehensive understanding of the organisation's business.

Prior to the purchase of any ICT infrastructures, including software, hardware, and network equipment, all informants in the empirical study expressed concern about planning ICT infrastructure in advance. This is to ensure that the right needs and specifications will be identified when planning project costs. Empirical study B has described a new element of system ownership that also influenced the implementation of legacy systems modernisation. The owner of the system needs to be determined when planning the project. This also allows them to be actively involved throughout the modernisation process.

Additionally, informants stated the importance of conducting a preliminary study before embarking on a modernisation project. This activity is important in collecting related information on the current situation of the systems, the readiness of the organisation, and the citizens before entering the next phase of modernisation. The initial stage involved a study of the current system (as-is), and the impact study to determine the impact of the modernisation and benchmarking. Benchmarking needs to be implemented so that agencies can take best practices from other countries that have successfully implemented citizen-centric digital government.

For the implementation of citizen-centric legacy systems modernisation, the informants also stated that it is essential to plan the involvement of the people, including determining the categories of citizens involved and the methods of involvement. In addition, the early views or feedbacks from the citizens need to be obtained through an initial citizens' survey in the planning phase. This has been informed by informants in both empirical studies.

4.2.2. System Requirements (Old and New)

The system requirements determination phase will involve the old and new system requirements for legacy systems modernisation. The old system requirements are implemented based on a reverse engineering process that involves the activities of understanding and extracting requirements. This process was derived from theoretical studies and was also explained in both empirical studies A and B. From their actual experience, two new elements have been mentioned, namely the understanding of the legacy systems through the existing users who were already savvy in using the systems and the existing documentation or outputs of the systems. This is to make sure that the important information is not left out.

In order to modernise the legacy systems in line with the citizens' needs, the gathering of requirements needs to be done with the involvement of the public. They are the exact

service recipients that understand what they need from the related service. The citizens' experiences in using the systems are important in assessing the needs and improvements needed. During analysing the requirements, the informants in empirical study B highlighted the element of mapping and selection to be done to ensure that only the still relevant needs will be taken into account. Empirical study B also mentioned that the specification of these requirements should consider the latest combination of old requirements.

4.2.3. Design and Development

In designing the system, relevant elements must be taken into account, including the interface, database, integration, and system architecture obtained in the theoretical study have been mentioned in the empirical study. However, empirical studies stated that the installation of hardware, software, and data migration should be implemented in this phase and not in the implementation phase as described in the theoretical study. Additionally, the new service that has been designed needs to be presented to the citizens in the form of a prototype. This needs to be done before system coding is executed.

4.2.4. Testing

In the theoretical study, the testing phase of the modernisation of legacy systems focused on performing test activities by taking into account the type of testing, test case, use case, and scenario. However, the informants of the empirical study stressed that the test requirements should be determined early so that the testing process will be carried out smoothly. In addition, the informants also stated that test reports that include errors and change requests need to be provided. These two factors were also activities described as a testing process according to international standards of the International Organisation for Standardization (ISO) [85].

Informants of empirical study B confirmed that this phase requires only the involvement of the people from the implementing agency. The system needs to be tested thoroughly through alpha testing by the testing team to make sure it works properly without errors before being implemented to the public.

4.2.5. Implementation

As stated by the informants earlier, the installation of ICT infrastructure needs to be implemented early during the design and development phase. Therefore, the latest application and data need to be transferred to the production environment during this phase. Besides that, the ICT infrastructure needs to be examined to ensure that the system environment works well in providing services to the citizens through the new modernised system. This is especially important to the agencies with branches and hardware installed in a distributed environment at their respective branches.

Before launching the actual implementation, the informants of empirical study B stated that the system needs to be implemented first on a pilot basis. Implementation on a smaller scale is more appropriate since the public will be involved for the first time after the system is ready. This will enable us to fix initial problems encountered before actual implementation on a larger scale. An important element in the involvement of the people during the pilot stage is to hold awareness sessions and get feedback from the citizens through beta testing. Their feedback on this completed system is important, and related improvements need to be made.

After the system is piloted for an agreed period, the system needs to be implemented for all the citizens involved. The completed system should be announced to the agency's top management as well as to the public. The outreach session as a broader involvement of the public needs to be organised as obtained in empirical study A. It was also highlighted by the informants in empirical study B as one of the ways of engaging the public during the actual implementation to the citizen.

Through the knowledge of the informants in empirical study B, the system handover of the process from the vendor or to the business owners must also not be overlooked.

This element will indirectly affect the subsequent implementation of the project. The handover process from the vendor needs to make sure the source code from the vendor is working well. After the system has been implemented successfully for a period of time, the handover process to the relevant business owner should be done. This is important to ensure long-term system support by the owners to the citizens.

4.2.6. Citizens' Involvement

One of the important factors in executing citizen-centric modernisation is the citizens' involvement. However, in the theoretical studies, specific citizens' involvement methods for the modernisation of legacy systems were not obtained. The findings from the empirical study A and B confirmed that citizens' involvement needs to be implemented for the modernisation of the legacy system of citizen-centric digital government, and they explained the relevant methods for that.

Citizens' involvement is needed at every phase of the modernisation of the legacy system, as explained earlier in the phases activities. The empirical study has discussed the importance of ensuring that a related category of people is involved in every phase of modernisation. This includes the citizens who are the recipients of government services as well as the citizens who are the implementers of the government services. The informants also described the appropriate methods of involvement implemented for the public sector. In addition to the use of social media and awareness sessions mentioned in theoretical studies, empirical studies also explained other methods of involvement. These include interviews, workshops, outreach programs, user experience studies, and complaints or feedback submitted by citizens through the agency's portals or mass media.

4.3. Organisation Aspect

Factors such as resources, change acceptance, and culture were organisational environment factors that influence the modernisation of legacy systems obtained from the theoretical studies. Empirical studies have also mentioned that those factors influence the modernisation of legacy systems in their respective agencies. However, three new factors, namely politics, bureaucracy, and mandate were discussed in detail by the informants that influenced the modernisation of the legacy system of citizen-centric digital government. Another organisational-related factor influencing the implementation of legacy systems modernisation highlighted in empirical study B is private sector cooperation. Through this model, qualified companies have the opportunity to work together and demonstrate their abilities in providing the best service to the citizens. The company will bear the costs involved, and they will get paid through the citizens or other institutions involved.

4.4. Product Aspect

The factors related to the products obtained from the theoretical study consist of three, namely system quality, data quality, and service quality. Each factor has its associated elements.

The empirical studies also stated the importance of the three quality factors to ensure that citizens receive the best service from the government. However, some elements were explained in detail specifically for the citizen-centric products based on their actual experience and situation in the public sector.

For product quality, the usability elements, including a simple and user-friendly system were important as the citizens who receive the benefits of government services come from various skill categories. This element is important in attracting more people to use the system. As for data quality, in the era of digital government that emphasises data integration and sharing, the elements of compliance and openness are essential.

The empirical study B has also detailed the quality of services by pointing out a few elements. The element of satisfaction by the citizens is an important factor in evaluating quality services. In addition, the elements of efficiency and effectiveness were seen as too subjective to be measured. They were more suitable to be replaced with the features of citizen-centric digital government that were more common in this era which are end-

to-end, integrated, and responsive services. The online services offered to the citizens now need to be completed from start to finish of the service through the same system, without manual intervention such as counter service. The end-to-end and integrated service demonstrates efficiency and effectiveness as they can optimise the performance of the services provided to the citizens. The services they receive are hassle-free and save their time and cost. Responsiveness becomes an important element as a feature of citizen-centric service. Service efficiency is assessed based on the agency's ability to respond or interact with the citizens' problems and queries in a timely manner.

The integration of findings from theoretical and empirical studies is summarised in Table 3 below. The number of informants that have stated the related factors and elements were included in the empirical columns.

Table 3. The Integration of Findings from Theoretical and Empirical Studies.

Factor	Element	Theoretical	Empirical A	Empirical B
		People Aspect		
Citizen	ICT Skill	√	√ (1/5)	√ (12/14)
	Willingness	-	-	√ (12/14)
Top Management	Support	√	√ (2/5)	√ (14/14)
	Citizen soul	-	-	√ (10/14)
	Digital mindset	-	-	√ (6/14)
Project Director	Leadership	-	-	√ (10/14)
	Network	-	-	√ (10/14)
Project manager	Experience	√	√ (2/5)	√ (14/14)
	Knowledge	√	√ (1/5)	√ (14/14)
	Leadership	√	√ (3/5)	√ (14/14)
Project Team/Testing Team	Technical skill	√	√ (4/5)	√ (14/14)
	Domain knowledge	√	√ (4/5)	√ (14/14)
	Communication skill	√	√ (1/5)	x
	Relationship	√	-	x
	Attitude	√	√ (1/5)	√ (14/14)
	Soft Skill	-	-	√ (3/14)
	Certification	-	-	√ (13/14)
		Process Aspect		
		Planning		
Organisation requirements	Business strategy	√	√ (2/5)	√ (13/14)
	Policy	√	√ (3/5)	√ (13/14)
Involvement requirements	The citizens involved	-	√ (5/5)	√ (10/14)
	Method	√	√ (4/5)	√ (7/14)
Preliminary study	As-is system	√	√ (2/5)	√ (14/14)
	Impact study	-	-	√ (10/14)
	Benchmarking	-	-	√ (6/14)
Citizens' survey	Early feedbacks	-	√ (3/5)	√ (14/14)
Project requirement	Scope	√	√ (2/5)	√ (14/14)
	Time	√	√ (2/5)	√ (14/14)
	Cost	√	√ (2/5)	√ (14/14)
	Human Resource	√	√ (4/5)	√ (14/14)
	Technique	√	√ (5/5)	√ (14/14)
	ICT Infrastructure	-	√ (4/5)	√ (14/14)
	Ownership	-	-	√ (12/14)

Table 3. *Cont.*

Factor	Element	Theoretical	Empirical A	Empirical B
System Requirements				
(a) Old Requirements				
Understanding of system	System architecture	√	√ (4/5)	√ (14/14)
	System users	-	√ (3/5)	√ (14/14)
	System output	-	√ (2/5)	√ (14/14)
Extraction of requirements	Business rules	√	√ (5/5)	√ (14/14)
	Business logic	√	√ (5/5)	√ (14/14)
	Data	√	√ (4/5)	√ (14/14)
	Legacy specification	√	√ (1/5)	√ (14/14)
(b) New Requirements				
Requirements gathering	Citizens experience	-	√ (3/5)	√ (14/14)
Analysis	Mapping and selection	-	-	√ (14/14)
Specification	Old and new	-	-	√ (13/14)
Design & Development				
Design implementation	Interface	√	√ (1/5)	√
	Database	√	√ (1/5)	√
	Integration	√	√ (1/5)	√ (14/14)
	System architecture	√	√ (1/5)	√ (14/14)
Prototype presentation	New service design	-	-	√ (7/14)
ICT Infrastructure installation	Hardware and software	-	√ (1/5)	√ (14/14)
	Data migration	-	√ (1/5)	√ (14/14)
Development implementation	Coding	√	√ (1/5)	√ (14/14)
Testing				
Testing requirements	Testing type	√	√ (3/5)	√ (14/14)
	Case and scenario	√	√ (2/5)	√ (14/14)
Testing implementation	Alpha testing	√	√ (2/5)	√ (13/14)
Test report	Bugs and change request	-	√ (1/5)	√ (14/14)
Implementation				
Actual environment setting	ICT infrastructure examination	-	-	√ (10/14)
	Application and data	√	√ (1/5)	√ (14/14)
Pilot implementation	Awareness	-	-	√ (10/14)
	Beta testing	-	-	√ (10/14)
Actual implementation	Outreach program	-	√ (1/5)	√ (6/14)
	Monitoring	√	√ (1/5)	√ (14/14)
	Training	√	√ (4/5)	√ (14/14)
	Hand over	-	-	√ (12/14)
Product Aspect				
Service Quality	Effectiveness	√	√ (1/5)	x
	Efficiency	√	√ (3/5)	x
	Satisfaction	√	√ (3/5)	√ (12/14)
	Transparency	√	-	√ (10/14)
	Responsive	√	√ (1/5)	√ (10/14)
	End-to-end	-	-	√ (11/14)
	Integrated	-	-	√ (9/14)

Table 3. *Cont.*

Factor	Element	Theoretical	Empirical A	Empirical B
		Product Aspect		
Product Quality	Functionality	√	√ (4/5)	√ (14/14)
	Performance efficiency	√	√ (1/5)	√ (14/14)
	Usability	√	√ (4/5)	√ (12/14)
	Compatibility	√	√ (1/5)	√ (9/14)
	Reliability	√	√ (3/5)	-
	Security	√	√ (1/5)	√ (10/14)
	Maintainability	√	√ (2/5)	-
	Portability	√	√ (1/5)	-
Data Quality	Accuracy	√	-	√ (12/14)
	Completeness	√	√ (3/5)	√ (14/14)
	Currentness	√	√ (4/5)	-
	Compliance	√	-	√ (7/14)
	Openness	√	-	√ (12/14)
		Organisation Aspect		
Resource		√	√ (1/5)	√ (14/14)
Culture		√	-	√ (14/14)
Change acceptance		√	√ (2/5)	√ (14/14)
Politic		-	√ (4/5)	√ (14/14)
bureaucracy		-	√ (2/5)	√ (14/14)
mandate		-	√ (2/5)	√ (14/14)
Legend:				
√ The factor/element was mentioned				
- The factor/element was not mentioned				
x The factor/element was not agreed				

Based on the table above, each phase of the study provides important factors and elements for the modernisation legacy system. All the factors and elements obtained from the theoretical study have been stated either in the empirical A or the empirical B study. There are also factors and elements that were stated in all studies. Four elements were not agreed upon in the empirical study B namely communication skill, relationship, effectiveness, and efficiency and new elements were proposed to better fit the situation of citizen-centric digital government. In addition, there was an increase in new factors and elements in both empirical studies in accordance with the actual situation of public sector services.

5. Conclusions

Legacy systems modernisation has become a critical undertaking for the public sector in order to remain competitive in this new era. In order to implement modernisation successfully and fulfil the latest direction of the citizen-centric digital government, public sector agencies need comprehensive guidelines. This study has identified the factors and elements involved in implementing legacy systems modernisation for a citizen-centric digital government.

This study employed a qualitative methodology. Firstly, the theoretical study was carried out to analyse the literature reviews on the research topic to get an initial idea of the topic studied. Next, empirical study A was conducted using the phenomenology research method. The related factors and elements were gathered through individual interviews with 5 informants with real experience in the legacy systems modernisation in the public

sector agencies. To understand the process of legacy systems modernisation in detail, empirical study B was implemented using the grounded theory method through individual and focus group interviews with 14 informants from selected public sector agencies.

The results show that there are four important aspects in implementing the legacy systems modernisation for citizen-centric digital government, namely people, process, organisation, and product. Each aspect has its own set of key factors and elements that influence modernisation. The findings give a holistic roadmap for the public sector agencies in modernising legacy systems with the aim of a citizen-centric digital government. In addition, the combination of methods used and the discovery of new factors in this study have further expanded the literature in the field of information systems and software engineering.

This study also contains limitations throughout the implementation. The main limitation was the outbreak of the COVID-19 pandemic which has affected all areas and aspects of life including research. Specifically, in this study, it has affected conducting empirical research. It has led to a change in the method of conducting interviews. Physical interviews had to be postponed or cancelled. Some interviews had to be conducted online via video conferencing. All information regarding the study was channelled through email, phone and Whatsapp applications. These situations had actually made it difficult and disrupted the study plan in terms of resources and time. In addition, due to the researcher's location, the implementation of this study is in the context of the Malaysian public sector. Therefore, the findings of the study cannot be automatically used by other countries due to demographic and cultural differences. Therefore, this study can be expanded to the global level in producing a more accurate framework for the public sector.

Author Contributions: Conceptualization, H.A.B.; methodology, H.A.B., R.R. and H.A.B. writing—original draft preparation; R.R. and D.I.J.; review and editing, R.R. and D.I.J.; supervision, R.R.; funding acquisition. All authors have read and agreed to the published version of the manuscript.

Funding: This work is funded by Universiti Kebangsaan Malaysia (FRGS/1/2020/ICT03/UKM/02/1).

Institutional Review Board Statement: Ethical review and approval were not needed for this study because it does not involve humans or any intervention towards humans directly. This study is related to the technology process-oriented where it explains the meaning of the informants' experience in understanding the entire process of the organisation in implementing the modernisation of the legacy systems for the digital government. The result of the study is a guideline in terms of factors and elements that influence the implementation of legacy systems modernisation.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Albuquerque, A.B.; Cruz, V.L. Implementing DevOps in Legacy Systems. *Adv. Intell. Syst. Comput.* **2019**, *860*, 143–161.
2. Abdellatif, M.; Shatnawi, A.; Mili, H.; Moha, N.; El Boussaidi, G.; Hecht, G.; Privat, J.; Gueheneuc, Y.G. A Taxonomy of Service Identification Approaches for Legacy Software Systems Modernization. *J. Syst. Softw.* **2021**, *173*, 110868. [CrossRef]
3. Da Silva, C.E.; Justino, Y.d.L.; Adachi, E. SPReaD: Service-Oriented Process for Reengineering and DevOps: Developing Microservices for a Brazilian State Department of Taxation. *Serv. Oriented Comput. Appl.* **2022**, *16*, 1–16. [CrossRef]
4. Jha, S.; Jha, M.; O'Brien, L.; Wells, M. Supporting decision making with big data integrating legacy systems and data. In Proceedings of the 2017 4th Asia-Pacific World Congress on Computer Science and Engineering (APWC), Nadi, Fiji, 12–14 December 2016; pp. 120–128.
5. Khadka, R.; Batlajery, B.V.; Saeidi, A.M.; Jansen, S.; Hage, J. How do professionals perceive legacy systems and software modernization? In Proceedings of the 36th International Conference on Software Engineering-ICSE 2014, Hyderabad, India, 31 May–7 June 2014; pp. 36–47.
6. Bhavsar, C. Hybrid Project Management Approach for Software Modernization. Master's Thesis, Harrisburg University of Science and Technology, Harrisburg, PA, USA, 2016.
7. Seetharamatantry, H.; Murulidhar, N.; Chandrasekaran, K. Implications of Legacy Software System Modernization—A Survey in a Changed Scenario. *Int. J. Adv. Res. Comput. Sci.* **2017**, *8*, 1002–1008.
8. Raksi, M. *Modernizing Web Application: Case Study*; Aalto University: Espoo, Finland, 2017.
9. Khan, M.; Ali, I.; Nisar, W.; Saleem, M.Q.; Ahmed, A.S.; Elamin, H.E.; Mehmood, W.; Shafiq, M. Modernization Framework to Enhance the Security of Legacy Information Systems. *Intell. Autom. Soft Comput.* **2022**, *32*, 543–555. [CrossRef]

10. Alkhalil, A. Evolution of Existing Software to Mobile Computing Platforms: Framework Support and Case Study. *Int. J. Adv. Appl. Sci.* **2021**, *8*, 100–111. [CrossRef]
11. Perez-Castillo, R.; Serrano, M.A.; Piattini, M. Software Modernization to Embrace Quantum Technology. *Adv. Eng. Softw.* **2021**, *151*, 102933. [CrossRef]
12. Paulin, A. KTLO & Brownfield: Overcoming Challenges When Modernizing Process Automation and Business Intelligence. *Cent. East. Eur. eDem eGov Days* **2022**, *341*, 241–249.
13. Gartner. Gartner Says Government CIOs Must Flip from "Legacy First" to "Digital First". Available online: https://www.gartner.com/en/newsroom/press-releases/2015-04-02-gartner-says-government-cios-must-flip-from-legacy-first-to-digital-first (accessed on 19 February 2019).
14. Deloitte Access Economics. *Digital Government Transformation*; Australia Adobe: Sydney, Australia, 2015; pp. 1–74.
15. Iannino, V.; Colla, V.; Mocci, C.; Matino, I.; Dettori, S.; Kolb, S.; Plankenbühler, T.; Karl, J. Multi-Agent Systems to Improve Ef Fi Ciency in Steelworks. *Matériaux Tech.* **2022**, *109*, 502. [CrossRef]
16. Aprianti, V.; Sahid, S. The Relationship between Teachers' Competency and Fourth Industrial Revolution (4ir) Learning among Economics Teachers. *Univers. J. Educ. Res.* **2020**, *8*, 63–70. [CrossRef]
17. Ramli, S.; Rasul, M.S.; Affandi, H.M. Sustainable Development: Needs of Green Skills in the Fourth Industrial Revolution (4IR). *Int. J. Acad. Res. Bus. Soc. Sci.* **2018**, *8*, 1082–1095. [CrossRef]
18. Hamid, M.S.R.A.; Masrom, N.R.; Mazlan, N.A.B. The Key Factors of the Industrial Revolution 4.0 in the Malaysian Smart Manufacturing Context. *Int. J. Asian Bus. Inf. Manag.* **2022**, *13*, 1–19. [CrossRef]
19. CGI. Industry 4.0 Making Your Business More Competitive. Available online: https://www.cgi.com/en/media/whitepaper/Industry-4-making-your-business-more-competitive (accessed on 15 October 2019).
20. Krishnan, S.; Mathai, A.; Singhee, A.; Kumar, A.; Agarwal, S.; Raghunath, K.N.; Wenk, D. Incremental analysis of legacy applications using knowledge graphs for application modernization. In Proceedings of the ACM International Conference, Bengaluru, India, 8–10 January 2022; pp. 250–254.
21. Alexandrova, A.; Rapanotti, L.; Horrocks, I. The legacy problem in government agencies: An exploratory study. In Proceedings of the 16th Annual International Conference on Digital Government Research, Phoenix, AZ, USA, 27–30 May 2015; pp. 150–159.
22. Matthiesen, S.; Bjorn, P. Why replacing legacy systems is so hard in global software development: An information infrastructure perspective. In Proceedings of the 18th ACM International Conference on Computer-Supported Cooperative Work and Social Computing (CSCW), Vancouver, BC, Canada, 14–18 March 2015; pp. 876–890.
23. Thapa, B.E.P.; Niehaves, B.; Seidel, C.E.; Plattfaut, R. Citizen Involvement in Public Sector Innovation: Government and Citizen Perspectives. *Inf. Polity* **2015**, *20*, 3–17. [CrossRef]
24. Osborne, S.P.; Radnor, Z.; Strokosch, K. Co-Production and the Co-Creation of Value in Public Services: A Suitable Case for Treatment? *Public Manag. Rev.* **2016**, *18*, 639–653. [CrossRef]
25. Saeed, S.; Ramayah, T.; Mahmood, Z. (Eds.) *User Centric E-Government—Challenges and Opportunities*; Springer International Publishing: Cham, Switzerland, 2017.
26. Malek, J.A.; Lim, S.B.; Yigitcanlar, T. Social Inclusion Indicators for Building Citizen-Centric Smart Cities: A Systematic Literature Review. *Sustainability* **2021**, *13*, 376. [CrossRef]
27. Althani, B.; Khaddaj, S.; Makoond, B. A quality assured framework for cloud adaptation and modernization of enterprise applications. In Proceedings of the 2016 IEEE Intl Conference on Computational Science and Engineering (CSE) and IEEE Intl Conference on Embedded and Ubiquitous Computing (EUC) and 15th Intl Symposium on Distributed Computing and Applications for Business Engineering (DCABES), Paris, France, 24–26 August 2016; pp. 634–637.
28. Sanchez, E.S.; Clemente, P.J.; Conejero, J.M.; Prieto, A.E. Business Process Execution from the Alignment between Business Processes and Web Services: A Semantic and Model-Driven Modernization Process. *IEEE Access* **2020**, *8*, 93346–93368. [CrossRef]
29. Wolfart, D.; Schmeing, E.; Geraldino, G.; Villaca, G.; Paza, D.; Paganini, D.; Assunção, W.K.G.; Da Silva, I.F.; Santander, V.F.A. Towards a process for migrating legacy systems into microservice architectural style. In Proceedings of the Escola Regional de Engenharia de Software, Brazil (Online), 1–3 December 2021; pp. 255–264.
30. Moutaouakkil, A.; Mbarki, S. PHP Modernization Approach Generating KDM Models from PHP Legacy Code. *Bull. Electr. Eng. Inform.* **2020**, *9*, 247–255. [CrossRef]
31. Khan, M.; Ali, I.; Mehmood, W.; Nisar, W.; Aslam, W.; Shafiq, M.; Choi, J.G. CMMI Compliant Modernization Framework to Transform Legacy Systems. *Intell. Autom. Soft Comput.* **2021**, *27*, 311–331. [CrossRef]
32. Nordin, N.; Norman, H. Mapping the Fourth Industrial Revolution Global Transformation On 21st Century Education on the Context of Sustainable Development. *J. Sustain. Dev. Educ. Res.* **2018**, *2*, 1–7. [CrossRef]
33. Kim, Y.; Lee, J.; Kang, J.; Park, S.; Jang, D. A Study on the Development of Medical Robotics Technology Commercialization Model. *J. Adv. Inf. Technol.* **2021**, *12*, 148–152. [CrossRef]
34. Fatorachian, H.; Kazemi, H. Impact of Industry 4.0 on Supply Chain Performance. *Prod. Plan. Control* **2021**, *32*, 63–81. [CrossRef]
35. Müller, J.M.; Kiel, D.; Voigt, K.I. What Drives the Implementation of Industry 4.0? The Role of Opportunities and Challenges in the Context of Sustainability. *Sustainability* **2018**, *10*, 247. [CrossRef]
36. Varshney, A.; Garg, N.; Nagla, K.S.; Nair, T.S.; Jaiswal, S.K.; Yadav, S.; Aswal, D.K. Challenges in Sensors Technology for Industry 4.0 for Futuristic Metrological Applications. *Mapan J. Metrol. Soc. India* **2021**, *36*, 215–226. [CrossRef]

37. Lindgren, I.; van Veenstra, A.F. Digital government transformation. In Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age, Delft, The Netherlands, 30 May–1 June 2018; pp. 1–6.
38. Huijgens, H.; Van Deursen, A.; Van Solingen, R. Success factors in managing legacy system evolution. In Proceedings of the International Conference on Software and Systems Process, Austin, TX, USA, 14–15 May 2016; pp. 96–105.
39. Bakar, H.A.; Razali, R.; Jambari, D.I. Legacy Systems Modernisation for Citizen-Centric Digital Government: A Conceptual Model. *Sustainability* **2021**, *13*, 13112. [CrossRef]
40. Cho, E.S.; Cha, J.E.; Yang, Y.J. MARMI-RE: A method and tools for legacy system modernization. In Proceedings of the International Conference on Software Engineering Research and Applications (SERA), Los Angeles, CA, USA, 5–7 May 2004; pp. 42–57.
41. Baghdadi, Y.; Al-Bulushi, W. A Guidance Process to Modernize Legacy Applications for SOA. *Serv. Oriented Comput. Appl.* **2013**, *9*, 41–58. [CrossRef]
42. Marquez, L.; Rosado, D.G.; Mouratidis, H.; Fernandez Medina, E. *SMiLe2Cloud—Security Migration of Legacy Systems to Cloud Computing*; University of Castilla-La Mancha: Ciudad Real, Spain, 2017.
43. Hassan, S.; Qamar, U.; Hassan, T.; Waqas, M. Software reverse engineering to requirement engineering for evolution of legacy system. In Proceedings of the 2015 5th International Conference on IT Convergence and Security (ICITCS), Kuala Lumpur, Malaysia, 24–27 August 2015; pp. 1–4.
44. Kamaruddin, K.; MdNoor, N. Citizen-centric demand model for transformational government systems. In Proceedings of the 21st Pacific Asia Conference on Information Systems (PACIS 2017), Langkawi, Malaysia, 16–20 July 2017; pp. 1–13.
45. Bell, D.; Nusir, M. Co-design for government e-service stakeholders. In Proceedings of the 50th Hawaii International Conference on System Science (HICSS-50), Hawaii, HI, USA, 4–7 January 2017; pp. 2539–2548.
46. Berntzen, L. Citizen-centric eGovernment services. In Proceedings of the 6th International Conference on Advances in Human-Oriented and Personalized Mechanisms, Technologies, and Services (CENTRIC), Venice, Italy, 27 September–1 October 2013; pp. 132–136.
47. Sahu, G.P.; Dwivedi, Y.K.; Rana, N.P.; Alryalat, M.A.A.; Tajvidi, M. Use of Social Media in Citizen-Centric Electronic Government Services. *Int. J. Electron. Gov. Res.* **2017**, *13*, 55–79.
48. Flores, C.C.; Rezende, D.A. Twitter Information for Contributing to the Strategic Digital City: Towards Citizens as Co-Managers. *Telemat. Inform.* **2018**, *35*, 1082–1096. [CrossRef]
49. Srimuang, C.; Cooharojananone, N.; Tanlamai, U.; Chandrachai, A. Development of an Open Government Data Assessment Model: User-Centric Approach to Identify the Weighted Components in Thailand. *Int. J. Electron. Gov.* **2018**, *10*, 276–295. [CrossRef]
50. Rajavat, E.A.; Tokekar, V. A quantitative model for the evaluation of reengineering risk in infrastructure perspective of legacy system. In Proceedings of the 2012 CSI 6th International Conference on Software Engineering (CONSEG), Madhay Pradesh, India, 5–7 September 2012; pp. 1–8.
51. Standish Group. *The Standish Group Report Chaos*; Standish Group International Inc.: Boston, MA, USA, 2014; pp. 1–16.
52. Sigwejo, A.; Pather, S. A Citizen-Centric Framework for Assessing E-Government Effectiveness. *Electron. J. Inf. Syst. Dev. Ctries.* **2016**, *74*, 1–27. [CrossRef]
53. Miah, S.J. The Role of End User in E-Government Application Development: A Conceptual Model in the Agricultural Context. *J. Organ. End User Comput.* **2012**, *24*, 69–85. [CrossRef]
54. Otieno, I.; Omwenga, E. Citizen-centric critical success factors for the implementation of e-Government: A case study of Kenya Huduma Centres. In Proceedings of the 2015 IST-Africa Conference, Lilongwe, Malawi, 6–8 May 2015; pp. 1–9.
55. OECD. Recommendation of the Council on Digital Government Strategies. 2014. Available online: https://www.oecd.org/gov/digital-government/Recommendation-digital-government-strategies.pdf (accessed on 1 August 2019).
56. ISO. Software Product Quality Requirements and Evaluation (SQUARE)—Systems and Software Quality Model (ISO/IEC 25010:2011). Available online: https://www.iso.org/obp/ui/#iso:std:iso-iec:25010:ed-1:v1:en (accessed on 16 July 2019).
57. ISO. Software Product Quality Requirements and Evaluation (SQUARE)—Data Quality Model (ISO/IEC 25012:2008). Available online: https://www.iso.org/obp/ui/#iso:std:iso-iec:25012:ed-1:v1:en (accessed on 16 July 2019).
58. Warren, I.; Ransom, J. Renaissance: A method to support software system evolution. In Proceedings of the IEEE Computer Society's International Computer Software and Applications Conference, Oxford, UK, 26–29 August 2002; pp. 415–420.
59. Parasuraman, A.; Zeithaml, A.; Berry, L.L. SERVQUAL: A Multiple-Item Scale for Measuring Consumer Perceptions of Service Quality. *J. Retail.* **1988**, *64*, 12–37.
60. Kamaruddin, K.A.; Marni, U.S.; Noor, N.L.M. Conceptual Model for Assessment Tool to Measure Citizen-Centricity in E-Government Websites. *J. Theor. Appl. Inf. Technol.* **2018**, *96*, 8171–8182.
61. Berntzen, L.; Johannesen, M.R.; Ødegård, A. A citizen-centric public sector: Why citizen centricity matters and how to obtain it. In Proceedings of the CENTRIC 2016—The Ninth International Conference on Advances in Human-Oriented and Personalized Mechanisms, Technologies, and Services, Rome, Italy, 2–28 May 2016; pp. 14–20.
62. Abu Bakar, H.; Razali, R.; Jambari, D.I. An Initial Understanding of Legacy Systems Modernisation for Citizen-Centric Digital Government. *Int. J. Adv. Sci. Technol.* **2020**, *29*, 9930–9940.
63. Creswell, J.W. *Research Design: Qualitative, Quantitative and Mixed Method*, 4th ed.; SAGE Publications: Los Angeles, CA, USA, 2014.
64. Van Manen, M. But Is It Phenomenology? *Qual. Health Res.* **2017**, *27*, 775–779. [CrossRef] [PubMed]

65. Moustakas, C. *Phenomenological Research Methods*; SAGE Publications: Los Angeles, CA, USA, 1994.
66. Creswell, J.W.; Hanson, W.E.; Clark Plano, V.L.; Morales, A. Qualitative Research Designs: Selection and Implementation. *Couns. Psychol.* **2007**, *35*, 236–264. [CrossRef]
67. Saraswat, S.P. A phenomenological investigation of information and communications technology at a public sector enterprise in India. In Proceedings of the 15th Americas Conference on Information Systems (AMCIS 2009), California, CA, USA, 6–9 August 2009; pp. 1–9.
68. Andrade, A.D.; Techatassanasoontorn, A.A.; Singh, H. Phenomenology: Understanding the ICT4D experience. In Proceedings of the AMCIS 2017—Americas Conference on Information System, Boston, MA, USA, 10–12 August 2017; pp. 1–10.
69. Starks, H.; Brown Trinidad, S. Choose Your Method: A Comparison of Phenomenology, Discourse Analysis and Grounded Theory. *Qual. Health Res.* **2013**, *17*, 1372–1380. [CrossRef]
70. Groenewald, T. A Phenomenological Research Design Illustrated. *Int. J. Qual. Methods* **2017**, *3*, 42–55. [CrossRef]
71. Asnosike, P.; Ehrich, L.C.; Ahmed, P. Phenomenology as a Method for Exploring Management Practice. *Int. J. Manag. Pract.* **2012**, *5*, 205–224. [CrossRef]
72. Harris, Y.M. *A Phenomenological Study: Exploring the Needs, Wants, and Desires from the Voices of African-American Males Desiring to Graduate from Community College*; Liberty University: Lynchburg, VA, USA, 2016.
73. Bryant, A.; Charmaz, K. *The SAGE Handbook of Grounded Theory*; SAGE Publications: Los Angeles, CA, USA, 2007.
74. Birks, M.; Mills, J. *Grounded Theory: A Practical Guide*; SAGE Publications: Los Angeles, CA, USA, 2011.
75. Seidel, S.; Urquhart, C. On Emergence and Forcing in Information Systems Grounded Theory Studies: The Case of Strauss and Corbin. *J. Inf. Technol.* **2013**, *28*, 237–260. [CrossRef]
76. Creswell, J.W.; Creswell, J.D. *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*, 5th ed.; SAGE Publications: Los Angeles, CA, USA, 2018.
77. Mashel Kasem, S.A. *A Framework of Selecting Agile Methods in the Development of Software Products*; Universiti Kebangsaan Malaysia: Bangi, Malaysia, 2018.
78. Glaser, B.G.; Strauss, A.L. *The Discovery of Grounded Theory: Strategies for Qualitative Research*; A Division of Transaction Publishers: New Brunswick, NJ, USA, 1967.
79. Charmaz, K.; Bryant, A. Grounded theory. In *International Encyclopedia of Education*; Elsevier Ltd.: Amsterdam, The Netherlands, 2010; pp. 406–412.
80. Mack, N.; Woodsong, C.; MacQueen, K.M.; Guest, G.; Namey, E. *Qualitative Research Methods: A Data Collector's Field Guide*; Family Health International: Durham, NC, USA, 2005.
81. Charmaz, K. *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*; SAGE Publications: Los Angeles, CA, USA, 2006.
82. Strauss, A.; Corbin, J. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 3rd ed.; SAGE Publications: Los Angeles, CA, USA, 2008.
83. Noble, H.; Mitchell, G. What Is Grounded Theory? *Evid. Based Nurs.* **2016**, *19*, 34–35. [CrossRef]
84. Strauss, A.; Corbin, J. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 2nd ed.; SAGE Publications: Los Angeles, CA, USA, 1998.
85. Kwon, W. The Core of International Software Testing Standard, ISO/IEC29119. Available online: https://www.mstb.org/Downloadfile/WonilKwon-SoftwareTestingISOStandard29119.pdf (accessed on 10 March 2021).