Article

A Study of Current Socio-Technical Design Practices in the Industry 4.0 Context among Small, Medium, and Large Manufacturers in Minnesota and North Dakota

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Abstract: The implementation of flexible work arrangements in the modern work environment has increased in recent years. Jointly optimizing social and technical factors within an organization is necessary for the development of hybrid work environments. This study describes insights gleaned from a survey issued to SMEs and large manufacturers in Minnesota and North Dakota. The survey design focused on socio-technical theory, digital maturity, organizational learning, responsible autonomy, leadership, communication strategies, and reduced work week schedules. Insights were provided as to how these critical factors support sustainability initiatives, such as reduced work week schedules. The research assesses strengths and weaknesses in the current socio-technical design of manufacturing organizations in Minnesota and North Dakota that work towards and against implementing reduced daily work hour goals.

Keywords: socio-technical theory; responsible autonomy; reduced work week; organizational learning; flexible work arrangement; leadership; communication

1. Introduction

In 2022 the National Association of Manufacturers reported that there were 624 manufacturing firms in North Dakota as of 2019. As of 2021 manufacturing employment represented 27,000 employees. In addition, this organization also reported that 6387 manufacturers in Minnesota accounted for 320,000 employees [1]. In 2022, 34 percent of employed persons did some or all of their work at home and 69 percent of employed persons did some or all of their work at their workplace. On average, those who worked at home did so for 5.4 h on days they worked and those who worked at their workplace did so for 7.9 h [2].

The state of North Dakota’s Economic Development Foundation developed a Strategic Plan for 2017–2025, which includes a strategic vision for advanced manufacturing by assessing the critical areas of entrepreneurship and innovation. This report outlines the strategic responsibilities of the state to successfully implement a vision for continued growth. These include continuing to invest in university-based research and development conducted with the private sector that engages North Dakota in emerging technologies and work to fast-track commercialization, promote export trade, and continue investing in statewide talent strategies that address education, training, recruitment, and retention to support long-term sustainability goals [3]. Alternately, Enterprise Minnesota is a participant of the U.S. Department of Commerce’s Manufacturing Extension Program and has conducted surveys illustrating several key indicators of the current status of manufacturers in Minnesota. When surveyed, Minnesota manufacturing firms indicated that increasing productivity, developing company managers and leaders, effective strategic planning and implementation, and implementing and using automation were within the top ten drivers of the companies’ future growth [4].
The objective of this research is to evaluate the technical and social factors impacting modern manufacturers’ abilities to work in new and meaningful ways, such as through reduced work week schedules resulting from developing a culture of organizational learning, responsible autonomy, and promoting productivity and innovation.

This study is grounded in socio-technical theory as described by Davis et al., where the joint optimization of technical components, such as technology, processes, and infrastructure, and the social components of people, goals, and culture operate interdependently and efficiently [5]. When either the social or technical component is unattended a less than optimal outcome is observed. This study contributes to the literature on socio-technical systems theory by measuring the regional impact of socio-technical design among small and medium enterprises (SMEs) as well as large manufacturers.

This paper asks the following research questions to review the socio-technical readiness of manufacturers in Minnesota and North Dakota to instill reduced work week goals within their organizations.

Research Question 1: Will organizational learning have a significant positive correlation with achieving a reduced daily work hour goal?

Research Question 2: Will responsible autonomy have a significantly positive correlation with the promotion of productivity and innovation?

Research Question 3: Will responsible autonomy have a significantly positive correlation with organizational learning among regional manufacturers?

In reviewing these research questions, a research context, methodology, case study results assessing small, medium, and large manufacturers in Minnesota and North Dakota, discussion, and conclusion are provided.

2. Research Context

2.1. Socio-Technical Design in Industry 4.0 Adoption

The socio-technical framework assists with predictive work, such as determining productivity outcomes and labor scheduling. This organizational design theory is critical to designing and overseeing digital transformation projects. Individual and team-based initiatives support sustainability. Socio-technical system design is defined by ongoing improvement efforts [5]. Bastidas et al. described the socio-technical design of tasks, as an example, as a linear process of “planning tasks, testing tasks, embedding tasks, and enabling tasks”, which relates to the operational process outlined by Davis et al. Innovative technologies, such as digital twins, big data, artificial intelligence, machine learning, and IoT, are leveraged for digital transformation [6]. The digital transformation process or Industry 4.0 implementation allows manufacturing SMEs to have the ability to become more flexible, agile, and responsive to customer needs. Digital transformation can be integrated in design, planning, manufacturing, research and development, and service activities [7]. The structure of work, technology, and design practices are evolving and directly contribute to the manner of using socio-technical principles and applications.

The challenges to the adoption of the innovative technologies of Industry 4.0 among SMEs have been reported as a lack of employee knowledge and training capabilities on quality issues, cyber security, resistance to change, organizational culture, large data volume, integration of digital tools in infrastructure, data quality, and data ethics [8]. Cross training employees to understand skills from divisions outside their own strengthen internal capacities to conduct continuous research, analysis, and decision making, which are integral skills in developing employee adaptability [9]. In addition, the type of digital maturity of an organization provides an indication of how innovative and responsive to customer requirements the SME is likely to be [7]. The level of organizational focus on social factors, such as training and management support, also provides advantages to adopting Industry 4.0. Economic factors such as employee innovation and perceived usefulness also support Industry 4.0 adoption rates. The technical subsystem of holistic internal cooperation, knowledge diffusion, and appropriate use of techniques, equipment, and facilities also support digital transformation [10].
Project teams representing a diversity of stakeholders may work to ensure that human factors are integrated due to the team’s specific work knowledge that will contribute to socio-technical design [11]. An iterative approach in developing cross-trained employees is commencing in a specific area within the organization and scaling across divisions. This allows the organization to cautiously build the internal capabilities of employees to work with data and to interpret this successfully while quickly creating successful outcomes [12]. The socio-technical theory emphasizes joint optimization. However, when the conditions create an imbalance that optimizes social and technical factors without interaction, unpredictable and unplanned outcomes may occur [13]. Therefore, in the formation of predictive work, the identification of social aspects or human factors will require consideration in all three phases of conceptualization, design, and implementation of Industry 4.0 into the existing organization. To implement this socio-technical framework, the design must follow a pattern of “defining the technology, identifying the affected humans, identifying the technology, task scenario analysis and impacts, and outcome analysis” [14]. This implementation process involves data gathering, analysis and interpretation, summarizing the findings, testing the results with stakeholders, and iterating and amending.

2.1.1. Organizational Learning in the Socio-Technical Design Context

Organizational learning occurs when new knowledge is integrated into the organization, therefore being co-leveraged with current institutional knowledge to enhance systems, routines, rules, and procedures [15]. Principles for jointly optimizing both the social and technical aspects of an organization call for continuous learning to be instilled in the strategic vision. Feedback is provided for the individual and organizational perspectives to contribute to the ongoing development of the social aspects [16]. Modern socio-technical system design involves democratic dialogue, which encourages the democratic interrelation of stakeholders. Democratic dialogue moves away from one-directional communication and encompasses two-way dialogue, which is a participatory design process. It is important to note that a close knowledge with the work organization fosters the collaboration and solution focused model of democratic dialogue [17]. These eight learning principles were reported in a recent study:

- using a collaborative approach;
- creating collaboration across levels of stakeholders and contexts;
- high flexibility that accommodates time;
- ensuring usability and easy access;
- highly relevant for context;
- creating space for reflection;
- creating awareness for adaptive capacities;
- sharing examples of good practice [15].

Productive organizational learning encourages an organization to improve, learn in a productive manner, and engage in organizational inquiry on behalf of the organization. When operational problems arise, employees inquire and recommend new methods of solving them. The development of an organization that values employee learning is a first step to creating autonomy. When productive organizational learning is combined with responsible autonomy and employee control, an environment of socio-technical sustainability is created [18]. An enabler to integrating Industry 4.0 within the organization is shared learning, which is found concurrently with activities such as shared trust, shared visual understanding, and shared user perspectives [17].

Also, continuity is observed through organizational learning, which engages employees to improve task completion, job performance, and preventive work to reduce error rates within operations and anticipate future changes. Employees that exert control illustrate greater skill discretion and task authority, which are the foundation of responsible autonomy [18]. When assessing events or projects, the level of employee job control is critical to ensure the diversity of organizational design. Job control leads to employee engagement, which supports continuous learning and coping strategies to respond to disruptions and
challenges in workflow processes. Holistically, the professional development of employees who operate under an increased range of mobility leads to increased agility [19]. Socio-technical work design focuses on improving the diversification of task options rather than minimizing them [16]. Industry 4.0 technologies will alter work strategies, potentially with permanence. Therefore, understanding the human factors involved, such as employee experience, is critical to averting feelings of reduced autonomy, competence, and counterproductive work behaviors, as examples [20].

2.1.2. Reduced Work Weeks in the Socio-Technical Design Context

Industry 4.0 tools foster the support of communication and the diffusion of information. These new communication and information tools support collaboration between individuals, providing greater accessibility and security to the flow of data. The new cyber–physical technologies increase mobility of work times and locations, improve productivity, and enhance working conditions for employees [21]. In addition, flexible work arrangements are a result of trust as a management control strategy [22].

According to studies of the four-day work week, results have indicated improved employee morale and engagement and increased productivity [23]. The benefits of flexible work hours also include reduced turnover and absenteeism, increased work–life balance, greater motivation, increased training opportunities and staff qualifications, workplace mobility, and time savings due to lessened travel [24]. An increase in job and life satisfaction directly correlates to increased productivity due to employees’ assigned meanings to tasks [25]. According to a study conducted by Laursen, the autonomy to select work schedules was the most important form of its definition for young workers [26].

When employees view the company as a brand, social interaction is increased among employees, and happiness inspired at work positively influences employee performance [27]. Furthermore, according to a survey respondent of a study conducted by Whiteoak and Sullivan, it was stated that family culture is contrary to change, which holds a significantly different meaning compared to an employee culture that views the organization more objectively as a brand [28]. Employee engagement is essential in strategic planning to achieve desired productivity outcomes when following a four-day work week schedule.

An earlier study reported by Enehaug illustrated that a reduced daily work hour goal initiated better coordination and cooperation through the re-scheduling of work shifts. These factors served as a coping mechanism for the employees [18]. Whiteoak and Sullivan also conducted a socio-technical analysis of a manufacturing firm in Australia to assess the possibility of instilling a reduced work week goal or other alternative work arrangements at the organization. Three main recommendations resulted from the study, which were to incorporate a bottom-up approach to job crafting, explore micro-efficiencies, and value quality over quantity in work design as methods to achieve a reduced work week goal [28].

2.1.3. Responsible Autonomy in the Socio-Technical Design Context

An employee’s responsible autonomy is a core value of the socio-technical design process [29]. The socio-technical system theory notes that responsible autonomy describes the collective learning of employees to ensure skillsets are developed to promote a more independently self-governed work organization. Sustainability is supported by employees’ autonomy and control of workplace conditions, in other words self-leadership [30]. Furthermore, autonomy represents the employee’s freedom, independence, and discretion to determine methods of completing work and choice in selecting work schedules [31].

The goal of Industry 4.0 is to gain autonomy, decentralization, responsibility, and teamwork [32]. To achieve responsible autonomy, leadership takes a significant role in creating a work environment that supports flexibility in an employee’s place and time of work. When employees find meaning in their work and have the ability to customize technology, increased productivity is observed [16]. Designing a socio-technical organization jointly optimizes both technical and social systems, which aligns with employees’ values, thereby creating greater trust and job satisfaction [33].
that are desired are described as encompassing a diversification of skills, meaningful work, completing the whole task process, responsible autonomy, and adequate feedback [34]. Research illustrates that improving employee’s autonomy and task discretion correlates directly to the perceived benefit of flexible work arrangements [13].

One tool to support the development of responsible autonomy is creating cross-functional diagrams of processes and resources to identify the root cause of factors impacting workflow times and identifying the relationships influencing outcomes that occur [35]. Cross-functional diagrams encourage the design of adaptation, dynamic cooperation, and work distribution [36]. To support employee autonomy, cross-functional diagrams aid in providing discretion to design work flows to jointly optimize both technical and human factors, which assists with managing work demands and therefore reduces the potential for employee burnout. The mapping of interrelated activities and resources jointly by management and employees assists with accurately setting productivity goals, employee appraisals, and reduced work hours [37].

2.1.4. Leadership in the Socio-Technical Design Context

As businesses respond to increased product and service customization requirements, the upskilling of employees to manage digital technologies will be valuable [38]. Developing cross-functional teams allows for a bottom-up leadership approach where employees lead communication efforts to effectively integrate digital transformation. This communication structure is agile as it allows for the diffusion of operational information and innovation for the purpose of creating value and supporting an organization’s most successful strategic objectives within the internal and external subsystems of a socio-technical system [28,39]. In digital transformations, employees’ roles may change to incorporate tasks that are more engineering in nature, such as process control or continuous improvement, which will require a mindset of ongoing training [40].

Communicating as an organizational unit across departments and teams allows employees to identify areas of improvement that lead to greater operational efficiencies. This strategy provides an antecedent to moving to a reduced work week schedule [28]. A flexible organization activates the involvement of a variety of teams, units, and organizations for which the system design will be utilized [15]. Mutually transferring knowledge across all organizational levels elevates the employee to the role of knowledge worker [41]. Allowing for the continuous facilitation of employee training and feedback strengthens employee engagement and therefore operational effectiveness [31].

Leadership characteristics such as promoting self-awareness, listening, serving those on the team, helping people grow, coaching versus controlling, promoting safety, respect, and trust, and promoting the energy and intelligence of others are critical skills [42]. To maintain a high-level of employee trust, the development of standard operating procedures to guide the implementation of Industry 4.0 is essential. Standard operating procedures represent the technical subsystem of a socio-technical system. They provide a useful guide for an organization to prioritize processes carrying out digital transformation. The work processes, systems architecture, and data formats are then assessed to strategize the purpose for digital integration, data use, employee use, and return on investment [43]. When an organization holistically agrees upon these organizational procedures, a greater propensity for the robust adoption of Industry 4.0 is ensured [44].

Employee learning is a continuous process to maintain, as it fosters a sustainable growth advantage of trained personnel. Opportunities for employees to learn and encourage each other to learn, as well as provide feedback, support new technology adoption [45]. A flat organization rather than a hierarchical leadership structure provides a suitable environment for digital transformation as it represents an employee base with greater engagement and responsible autonomy. These organizational characteristics espouse a flexible, agile, learning, innovative, and communicative culture. Organizations that have exhibited a contrary structure have experienced lower levels of technology adoption. According to the socio-technical systems framework provided collectively by M.C. Davis,
Rose Challenger, Dharshana Jayewardene, and Chris Clegg, the six internal subsystems of people, culture, goals, processes, infrastructure, and technology are all equally important to strategically build internal capacity within to ensure successful interoperability and dynamic performance [46].

3. Research Methodology

The survey was used to collect data anonymously from regional manufacturers. The survey included the use of an online qualitative survey to gather the individual responses of 35 small, medium, and large manufacturers in Minnesota and North Dakota. The questionnaire requested participant information on the types of organizational design practices implemented within the work organization. The themes of the questions were organizational learning, responsible autonomy, communication strategy, reduced work hour goals, leadership characteristics, digital maturity, and socio-technical design.

The unit of analysis used in this research was the participants’ anonymous opinions about the socio-technical design employed within small-, medium-, and large-sized manufacturers.

The survey was designed by formulating the research questions based on nine academic research articles, which are referenced in the ‘Results’ section, on topics relevant to technology, processes, culture, people, infrastructure, and goals, which are integral to a socio-technical design framework.

The anonymous questionnaire was designed using Qualtrics. The analysis and interpretation of the data was based on a combination of a five-level Likert scale, open-ended questions, and defined multiple choice questions to prepare the assessment [47]. A five-tiered Likert scale was utilized that allowed for the responses of: (1) Extremely Unlikely, (2) Somewhat Unlikely, (3) Neither Likely nor Unlikely, (4) Somewhat Likely, and (5) Extremely Likely.

Participants were reached through the authors’ LinkedIn networks, UsBizData.com (accessed on 7 October 2023), an ND Department of Commerce list of manufacturers, Impact Dakota, and the Minn-Dak Manufacturers Association. The questionnaire provided 25 questions, and one format of the survey was provided to the public.

The online survey process was processed through Qualtrics and sent to approximately 2500 manufacturers. Thirty-five responses were received yielding a response rate of 1.4%. For the purposes of this study, small businesses employed 50 employees or less; medium-sized businesses employed between 50 and 250 employees; and large businesses employed more than 250 employees.

4. Results

The adoption levels of 22 socio-technical practices were assessed using a five-point Likert scale or multiple-choice option. The first three questions were demographic and inquired about business size based on the number of employees, the U.S. state in which the business is located, and the industry category, respectively. The survey assessed the current socio-technical organizational design practices and the motivation to adopt socio-technical work design, organizational learning, responsible autonomy, communication strategies, leadership skills, and flexible work arrangements conducive to implementing Industry 4.0 and a reduced work week schedule. Out of the 35 manufacturers surveyed that responded from the Minnesota and North Dakota markets, 22 were small, 7 were medium, and 6 were large.

An introductory message communicated to participants that anonymity and confidentiality would be ensured. The statistical analysis method of the Pearson correlation coefficient was leveraged to verify the pairwise linear relationships. In addition, simple frequency charts and cross tabulation comparison charts were generated. The relationships tested were 22 socio-technical design practices grouped into six socio-technical constructs of people, culture, goals, technology, processes, and infrastructure. A list representing only the survey questions that comprise each socio-technical construct is in Appendix A.
The questions within the category of the socio-technical construct of technology are noted below.

Which digital maturity level best describes your current organization? The following options were provided and participants were limited to selecting one option: paper-based; spreadsheet; commercial or customized quality IT solutions; product lifecycle management software integrated (i.e., SAP, Oracle, etc.); and the highest level of digital maturity—closed-loop manufacturing, closed-loop quality data, and product lifecycle management software integrated (Q4) [7].

How likely are employees to experience decision support through learning algorithms from various applications? (Q16) The following definition was provided: “Employee autonomy and decision-making are both impacted by learning algorithms in various IT applications. Algorithmic management can vary from decision support to judgment substitution for the employee. Learning algorithms shape the choices available to employees by automating decision-making, specifically by imposing predefined rules and by rapidly processing massive amounts of data” [48].

In reference to the prior question, how likely are employees to experience judgment substitution for the employee through learning algorithms from various applications, such as software platforms, as an example? (Q17) [48].

The Somewhat Likely and Extremely Likely Likert-scale responses from Minnesota and North Dakota businesses for Q16 were 11.43% and 0%, respectively. The same Likert responses for Q17 were 14.29% and 0%, respectively.

In response to Q4, workflow processes indicated that eight firms were paper-based, six used spreadsheets, seven leveraged commercial or customized quality IT solutions, eleven used product lifecycle management software integrated only, and three implemented close-loop manufacturing, closed-quality data, and product lifecycle management software that was integrated.

Q4 indicated that 20% of manufacturers were likely to establish a reduced daily work schedule. This represents one paper-based firm, two firms utilizing spreadsheets, one firm utilizing commercial or customized quality IT solutions, and one firm leveraging product lifecycle management software integrated, and no firms using closed-loop manufacturing, closed-loop quality data, and product lifecycle management software integrated. Figure 1 provides a visual representation of the responses.

Figure 1. The composition of the 20% of manufacturers (Q4) that indicated a likelihood to establish a reduced work schedule.
The questions within the category of the socio-technical construct of processes are noted below.

How likely is your organization to follow an operational process that includes these steps: data gathering, analysis and interpretation, summarizing the findings, testing the results with stakeholders, and iterating and amending as necessary to communicate recommendations to employees and stakeholders? (Q5) [5].

How likely is your organization to create cross-functional diagrams, which are used to map the workflow of interrelated activities and resources (i.e., product, workers, machine, material, workstation setup, production line, factory operations, external factors, etc.) that transform inputs into outputs, as well as to portray relationships among the various resources performing actions? (Q6) [35].

Which timeline(s) does your organization generate that include(s) key factors leading up to the event or scenario analyzed, grouped by the six factors of goals, people, buildings/infrastructure, technology, culture, and processes/procedures? The following options were provided and participants were allowed to select all that applied: long-standing (3+ months), issues immediately preceding the event (0–3 months), factors involved on the day, and the option to provide a customized response (Q7) [5].

How likely is your organization to continuously improve communication across departments and teams to instill employee engagement? (Q20) [28].

How likely is your organization to operate with standard operating procedures on work processes, systems architecture, and data formats? (Q23) [18].

How likely is your organization to recognize both technology and people dimensions to ensure that systems are highly efficient and contain better human characteristics that lead to better employee satisfaction? (Q25) [46].

Responses were combined from Minnesota and North Dakota business in the manufacturing industry for Q5, with the result that 25.71% of businesses responded Somewhat Likely and 20% Extremely Likely.

The comparable Likert responses for Q6 of the second socio-technical construct of processes were 25.71% and 14.29%, respectively. The same Likert responses for Q20 were 59.38% and 34.38%, respectively. The same Likert responses for Q23 were 28.13% and 56.25%, respectively. The same Likert responses for Q25 were 40.63% and 25%, respectively.

The responses for Q7 were as follows: 27.27% selected long-standing (3+ months) only; 9.09% selected long-standing (3+ months) and issues immediately preceding the event (0–3 months); 6.06% selected long-standing (3+ months), issues immediately preceding the event (0–3 months), and factors involved on the day; 27.27% selected issues immediately preceding the event (0–3 months) only; 3.03% selected issues immediately preceding the event (0–3 months) and factors involved on the day; and 15.15% selected factors involved on the day. Figure 2 displays the templated responses provided regarding the timelines used. Seven participants provided a customized response. The responses included statements such as “We use 3-month, 1 year, project specific, and long-term campaign strategy timelines” and “Some have a 1–3 month roll out, others 6–12 months”.

The questions within the category of the socio-technical construct of culture are noted below.

How likely is your organization characterized by continuity and adaptation of work processes and human factors? (Q8) [18].

How likely is your organization to promote the productivity and innovation of teams while minimizing conflicts? (Q9) [18].

Productive organizational learning has three classifications. Which classification best describes the level of productive organizational learning in your work organization? The following options were provided and participants were able to make one selection: organizational inquiry that improves the way tasks are solved, inquiry in which the organization explores and restructures values and criteria for better performance, and inquiry that betters the organizational learning of both types 1 and 2. (Q11) [18].
The responses for Q7 were as follows: 27.27% selected long standing (3+ months); 6.06% selected long term (0 to 3 months); and 6.06% selected short term (0 to 3 months) and factors involved on the day; and 15.15% selected immediate standing (3+ months), issues immediately preceding the event (0–3 months), and factors involved on the day. These responses are displayed in Figure 2.

How likely is your organization engaged in a culture of organizational learning? The following definition was provided to participants: “Organizational learning is defined as organizational inquiry that improves the ways tasks are solved, in for better performance. Employees are creative, innovative, and willing to continuously learn and develop” (Q22) [16].

How likely would your organization be defined as organizationally flexible? The following definition was provided to participants: “Organizational flexibility is defined as relying on flexible structures, applying leadership skills, and organizing processes and projects based on agile teamwork” (Q24) [46].

The Likert-scale responses of Somewhat Likely and Extremely Likely from Minnesota and North Dakota businesses in the manufacturing industry for Q8 of the socio-technical construct of culture were 34.29% and 25.71%, respectively. The same Likert responses for Q9 were 45.71% and 22.86%, respectively. In addition, the same Likert responses for Q22 were 34.38% and 25%, respectively. The same Likert responses for Q24 were 40.64% and 25%, respectively.

The responses for Q11 were as follows: 41.18% responded affirmatively to “organizational inquiry that improves the way tasks are solved”, 11.76% responded affirmatively to “inquiry in which the organization explores and restructures values”, and 47.06% responded affirmatively to “inquiry that betters the organizational learning of both types 1 and 2”. These responses are displayed in Figure 3.

How likely would your organization be defined as organizationally flexible? The following definition was provided to participants: “Organizational flexibility is defined as relying on flexible structures, applying leadership skills, and organizing processes and projects based on agile teamwork” (Q24) [46].

The responses for Q11 were as follows: 41.18% responded affirmatively to “organizational inquiry that improves the way tasks are solved”, 11.76% responded affirmatively to “inquiry in which the organization explores and restructures values”, and 47.06% responded affirmatively to “inquiry that betters the organizational learning of both types 1 and 2”. These responses are displayed in Figure 3.

Figure 2. In reference to Q7 on the types of timelines generated by the organization to analyze.

Figure 3. In reference to Q11 on the use of productive learning within the organization.
The questions within the category of the socio-technical construct of people are noted below.

How likely is your organization to specify roles, responsibilities, and/or tasks that are specific to that job when you are trying to optimize or streamline a process? (Q10) [18].

How likely is your organization to leverage a bottom-up problem-solving approach? The following example was provided to participants: “i.e., Job crafting that focuses on co-workers deciding and designing together to improve their work and workplaces during change”. (Q18) [28].

How likely is your organization to develop cross-functional teams? (Q19) [39].

How likely is your organization defined as engaging in responsible autonomy with employees and teams to achieve specific goals? The definition provided to participants was: “Responsible autonomy is defined as teams or groups having the discretion to judge and decide the organization, timing and pace of work tasks, which entails a relaxation of direct management supervision and helps to avoid ‘silo thinking’ by engaging the entire system”. (Q21) [16].

The responses were combined from Minnesota and North Dakota businesses in the manufacturing industry for Q10, with the result that 25.71% of businesses responded Somewhat Likely and 37.14% Extremely Likely.

The comparable Likert responses for Q18 were 48.57% and 11.43%, respectively. The same Likert responses for Q19 were 37.14% and 37.14%, respectively. The responses to question 21 were 40.63% and 21.88%, respectively.

The questions within the category of the socio-technical construct of infrastructure are noted below.

How likely is your organization to support allocation of resources and work to change and improve the production practices, organize work tasks, and strengthen internal cooperation? (Q12) [18].

The Somewhat Likely and Extremely Likely Likert-scale responses from Minnesota and North Dakota businesses in the manufacturing industry for Q12 were 37.14% and 31.43%, respectively.

The questions within the category of the socio-technical construct of goals are noted below.

How likely will establishing a reduced daily work hour goal serve as a way to jointly optimize the technical and human factors of your organization to achieve higher productivity and employee wellbeing? (Q13) [18].

Are flexible working hours applied in activities upstream or downstream of the production system? The following examples were provided: “i.e., design, protociling, manufacturing, fabrication, testing, quality control, packaging, and shipping”. The participants were provided with the option of responding ‘yes’ or ‘no’. If a ‘yes’ reply was provided the participant was encouraged to provide a customized additional response to include further information. (Q14) [21].

Are the hourly labor requirements and productivity goals achievable with a reduced hourly work week schedule when considering organizational factors? The following examples were provided: “i.e., product-related or design-related factors, worker-related factors, material-related factors, factory operations-related factors, and production-line related factors”. The participants were provided with the option of responding ‘yes’ or ‘no’. If a ‘yes’ reply was provided the participant was encouraged to provide a customized additional response to include further information. (Q15) [21].

The Somewhat Likely and Extremely Likely Likert-scale responses from Minnesota and North Dakota businesses in the manufacturing industry for Q13 were 14.29% and 5.71%, respectively.

The information submitted on Q14 indicates that 48.57% responded ‘yes’ and 51.43% responded ‘no’. The responses are displayed in Figure 4. The following customized responses were provided: (1) We are a brewery with a restaurant, taproom, and catering business. As long as the team communicates with each other and tasks get completed as scheduled, time is flexible. The restaurant has regular hours that we must maintain, but
staff schedule time off as needed. (2) activity. (3) Manufacturing and fabrication are flexed to accommodate jobs as necessary. (4) All work hours are flexible as long as they get their 40 h in. (5) We are not a public-based business, so hours can be flexible for our employees. (6) We have flexible work hours, up to a point. (7) Yes, for those types of support functions, very flexible working hours. The unwritten rule is that these functions should also put in a lot more time that 40 h/wk. (8) Flexibility is more available in the downstream process.

The cross tabulations of Q15 and Q12 on allocation of resources indicated that 3 out of 35 manufacturers positively correlate. The cross tabulations for Q15 and Q13 on the reduced daily work hour goal indicated that 4 out of 35 manufacturers positively correlate. The comparison of Q15 and Q16 on learning algorithms indicated that 1 out of 35 manufacturers positively correlate. Comparing Q15 to Q17 on judgment substitution noted no correlation. Question 15 compared to Q18 on bottom-up problem-solving approach indicated 5 affirmative responses out of 35. Question 15 compared to Q19 on developing cross-functional teams illustrated an outcome of 4 positive correlations out of 35. Question 15 compared to Q20 on continuously improving communication achieved the outcome of 6 affirmative responses out of 32. Question 15 compared to Q21 on responsible autonomy indicated 6 positive responses out of 32. Question 15 compared to Q22 on a culture of organizational learning illustrated 3 out of 32 positive correlations. Question 15 compared to Q23 on utilizing standard operating procedures indicated 4 positive correlations out of 32. Question 15 compared to Question 24 on organizational flexibility indicated 6 out of 32 positive correlations. Question 15 compared to Question 25 on socio-technical design led to four positive observations being noted.

Chi-Square tests were completed for Q14 and a strong positive relationship was found with Q12, Q13, Q21 (responsible autonomy), Q24, and Q25. A T Test was constructed and illustrated a strong positive relationship between Q14 and the socio-technical constructs of technology, processes, culture, people, and goals.

The results of Q15 indicate that 14.28% responded ‘yes’ and 85.72% responded ‘no’. The following customized responses were provided: (1) Delivery schedules. (2) Yes, we are struggling to keep employees busy with current workloads. (3) We can be flexible with hours, as needed.

Chi-Square tests were completed for Q15 and a strong positive relationship was found with Q13 and Q21 (responsible autonomy). A T Test was constructed and showed a strong positive relationship between Q15 and the socio-technical constructs of technology and goals.
All tables present the data similarly, where the top numbers represent the Pearson correlation coefficient, and the lower numbers represent the p-values. The null hypothesis is valued at zero between the variables. Included in Appendix A are the survey questions.

Table 1 shares the data provided by the 21 small manufacturers surveyed in Minnesota and North Dakota. The table displays the socio-technical design techniques, which are a bottom-up problem-solving approach, continuous communication across departments, responsible autonomy, organizational learning, the promotion of productivity and innovation teams while minimizing conflicts, and a reduced work week schedule. A significant and positive Pearson correlation coefficient was identified between Q18, which represents the socio-technical design technique of bottom-up problem solving, and Q21, which represents responsible autonomy. In addition, a significant and positive Pearson correlation coefficient was found between Q20, which represents continuous improvement of communication across departments and teams, and Q18, which represents bottom-up problem solving. Significantly positive Pearson correlation coefficients were also found between Q20 and Q22, as well as Q22 and Q9, which represent continuous communication and a culture of organizational learning, and organizational learning and the promotion of productivity and innovation of teams while minimizing conflicts, respectively.

Table 1. All small manufacturers from Minnesota and North Dakota surveyed.

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<tbody>
<tr>
<td>Q13</td>
<td>1.00000</td>
<td>0.14144</td>
<td>-0.32759</td>
<td>0.18253</td>
<td>-0.00993</td>
<td>0.08149</td>
</tr>
<tr>
<td>How likely will establishing a reduced daily work hour goal serve as a way to jointly optimize the technical and human factors of your organization to achieve higher productivity and employee wellbeing?</td>
<td>0.5408</td>
<td>0.1472</td>
<td>0.4284</td>
<td>0.9659</td>
<td>0.7255</td>
<td></td>
</tr>
<tr>
<td>Q18</td>
<td>0.5408</td>
<td>1.00000</td>
<td>0.46792</td>
<td>0.74514</td>
<td>0.32888</td>
<td>0.18483</td>
</tr>
<tr>
<td>How likely is your organization to leverage a bottom-up problem-solving approach?</td>
<td>0.1472</td>
<td>0.0324</td>
<td>0.0001</td>
<td>0.1455</td>
<td>0.4225</td>
<td></td>
</tr>
<tr>
<td>Q20</td>
<td>-0.32759</td>
<td>0.46792</td>
<td>1.00000</td>
<td>0.36809</td>
<td>0.53437</td>
<td>0.03522</td>
</tr>
<tr>
<td>How likely is your organization to continuously improve communication across departments and teams to instill employee engagement?</td>
<td>0.1472</td>
<td>0.0324</td>
<td>0.1006</td>
<td>0.0126</td>
<td>0.8795</td>
<td></td>
</tr>
<tr>
<td>Q21</td>
<td>0.18253</td>
<td>0.74514</td>
<td>0.36809</td>
<td>1.00000</td>
<td>0.22480</td>
<td>0.37329</td>
</tr>
<tr>
<td>How likely is your organization defined as engaging in responsible autonomy with employees and teams to achieve specific goals?</td>
<td>0.4284</td>
<td>0.0001</td>
<td>0.1006</td>
<td>0.3272</td>
<td>1.00000</td>
<td>0.56457</td>
</tr>
<tr>
<td>Q22</td>
<td>-0.00993</td>
<td>0.32888</td>
<td>0.53437</td>
<td>0.22480</td>
<td>1.00000</td>
<td>0.0077</td>
</tr>
<tr>
<td>How likely is your organization engaged in a culture of organizational learning?</td>
<td>0.9659</td>
<td>0.1455</td>
<td>0.0126</td>
<td>0.3272</td>
<td>0.56457</td>
<td></td>
</tr>
<tr>
<td>Q9</td>
<td>0.08149</td>
<td>0.18483</td>
<td>0.03522</td>
<td>0.37329</td>
<td>0.56457</td>
<td>1.00000</td>
</tr>
<tr>
<td>How likely is your organization to promote productivity and innovation of teams while minimizing conflicts?</td>
<td>0.7255</td>
<td>0.4225</td>
<td>0.8795</td>
<td>0.0956</td>
<td>0.0077</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 displays outcomes of the six medium-sized manufacturers in Minnesota and North Dakota. A significant and positive Pearson correlation coefficient was identified between an organization engaging in responsible autonomy with employees and teams to achieve specific goals (Q21) and the likelihood that establishing a reduced daily work hour goal serves to jointly optimize the technical and human factors of an organization to achieve higher productivity and employee wellbeing (Q13).
Table 2. All medium-sized manufacturers from Minnesota and North Dakota surveyed.

<table>
<thead>
<tr>
<th>Table 2 All medium-sized manufacturers from Minnesota and North Dakota surveyed.</th>
<th>Pearson Correlation Coefficients, N = 6</th>
<th>Q13</th>
<th>Q18</th>
<th>Q20</th>
<th>Q21</th>
<th>Q22</th>
<th>Q9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q13 How likely will establishing a reduced daily work hour goal serve as a way to jointly optimize the technical and human factors of your organization to achieve higher productivity and employee wellbeing?</td>
<td>1.00000</td>
<td>−0.07495</td>
<td>0.52145</td>
<td>0.82268</td>
<td>0.18210</td>
<td>−0.42400</td>
<td></td>
</tr>
<tr>
<td>Q18 How likely is your organization to leverage a bottom-up problem-solving approach?</td>
<td>−0.97495</td>
<td>1.00000</td>
<td>0.15811</td>
<td>0.21437</td>
<td>0.38651</td>
<td>0.53033</td>
<td></td>
</tr>
<tr>
<td>Q20 How likely is your organization to continuously improve communication across departments and teams to instill employee engagement?</td>
<td>0.52145</td>
<td>0.15811</td>
<td>1.00000</td>
<td>0.54233</td>
<td>0.76827</td>
<td>0.44721</td>
<td></td>
</tr>
<tr>
<td>Q21 How likely is your organization defined as engaging in responsible autonomy with employees and teams to achieve specific goals?</td>
<td>0.82268</td>
<td>0.21437</td>
<td>0.54233</td>
<td>1.00000</td>
<td>0.53029</td>
<td>−0.24254</td>
<td></td>
</tr>
<tr>
<td>Q22 How likely is your organization engaged in a culture of organizational learning?</td>
<td>0.18210</td>
<td>0.38651</td>
<td>0.76827</td>
<td>0.53029</td>
<td>1.00000</td>
<td>0.62470</td>
<td></td>
</tr>
<tr>
<td>Q9 How likely is your organization to promote productivity and innovation of teams while minimizing conflicts?</td>
<td>−0.42400</td>
<td>0.53033</td>
<td>0.44721</td>
<td>−0.24254</td>
<td>0.62470</td>
<td>1.00000</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 displays outcomes of the five large-sized manufacturers in Minnesota and North Dakota. With alpha significant at less than 0.05, there were no significantly positive correlations identified between organizational learning and reduced daily work hour goals, responsible autonomy and the promotion of productivity and innovation, and responsible autonomy and organizational learning.

Table 4 measures the socio-technical constructs of all manufacturers surveyed, which are noted as the technical subsystems of technology, processes, infrastructure and social subsystems of culture, people, and goals. A strong and positive Pearson correlation coefficient was observed between the following six relationships: processes and culture, processes and people, processes and infrastructure, culture and people, culture and infrastructure, and infrastructure and people. A moderate and positive relationship was observed between the following two relationships: technology and processes and technology and goals.

The number of observations used for a pair of variables is the number that provided data for both variables in the pair. There is no other selection criterion for the Pearson correlation coefficient determination. Therefore, in the case of the 31 observations in Table 4, as an example, there were 4 participants of the total 35 manufacturers that did not provide complete data for the socio-technical constructs in question.

Table 5 displays the relationship between digital maturity level and hourly labor requirements and productivity goals being achievable with a reduced hourly work week schedule when considering organizational factors. Three out of thirty-five or 8.57% of businesses responded in the affirmative that they utilized commercial or customized quality IT solutions or product lifecycle management software integrated into their operations. No businesses that utilized closed-loop manufacturing, closed-loop quality data and product lifecycle management software combined responded affirmatively.
Table 3. All large-sized manufacturers from Minnesota and North Dakota surveyed.

<table>
<thead>
<tr>
<th>Pearson Correlation Coefficients, N = 5</th>
<th>Q13</th>
<th>Q18</th>
<th>Q20</th>
<th>Q21</th>
<th>Q22</th>
<th>Q9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q13 How likely will establishing a reduced daily work hour goal serve as a way to jointly optimize the technical and human factors of your organization to achieve higher productivity and employee wellbeing?</td>
<td>1.0000</td>
<td>-0.4662</td>
<td>0.4252</td>
<td>0.5000</td>
<td>0.0000</td>
<td>-0.6455</td>
</tr>
<tr>
<td>Q18 How likely is your organization to leverage a bottom-up problem-solving approach?</td>
<td>-0.4662</td>
<td>1.0000</td>
<td>-0.2784</td>
<td>0.2331</td>
<td>-0.3616</td>
<td>0.3616</td>
</tr>
<tr>
<td>Q20 How likely is your organization to continuously improve communication across departments and teams to instill employee engagement?</td>
<td>0.4252</td>
<td>-0.2784</td>
<td>1.0000</td>
<td>-0.4252</td>
<td>0.7637</td>
<td>0.3273</td>
</tr>
<tr>
<td>Q21 How likely is your organization defined as engaging in responsible autonomy with employees and teams to achieve specific goals?</td>
<td>0.5000</td>
<td>0.2331</td>
<td>-0.4252</td>
<td>1.0000</td>
<td>-0.6455</td>
<td>-0.6455</td>
</tr>
<tr>
<td>Q22 How likely is your organization engaged in a culture of organizational learning?</td>
<td>0.0000</td>
<td>-0.3616</td>
<td>0.7637</td>
<td>-0.6455</td>
<td>1.0000</td>
<td>0.6667</td>
</tr>
<tr>
<td>Q9 How likely is your organization to promote productivity and innovation of teams while minimizing conflicts?</td>
<td>-0.6455</td>
<td>0.3616</td>
<td>0.3273</td>
<td>-0.6455</td>
<td>0.6667</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Table 4. Socio-technical construct comparison of all Minnesota and North Dakota manufacturers surveyed.

<table>
<thead>
<tr>
<th>Pearson Correlation Coefficients</th>
<th>Technology</th>
<th>Processes</th>
<th>Culture</th>
<th>People</th>
<th>Infrastructure</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prob &gt;</td>
<td>r</td>
<td>under H0: Rho = 0</td>
<td>Number of Observations</td>
<td>Technology</td>
<td>Processes</td>
<td>Culture</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------</td>
<td>-----------</td>
<td>---------</td>
<td>--------</td>
<td>----------------</td>
<td>-------</td>
</tr>
<tr>
<td>Technology</td>
<td>1.0000</td>
<td>0.38014</td>
<td>0.20899</td>
<td>0.15564</td>
<td>0.06698</td>
<td>0.47906</td>
</tr>
<tr>
<td>32</td>
<td>0.38014</td>
<td>1.0000</td>
<td>0.79181</td>
<td>0.77428</td>
<td>0.68667</td>
<td>0.18294</td>
</tr>
<tr>
<td>Processes</td>
<td>0.0319</td>
<td>0.2592</td>
<td>0.3950</td>
<td>0.7157</td>
<td>0.0055</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>0.20899</td>
<td>0.79181</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.3162</td>
</tr>
<tr>
<td>Culture</td>
<td>0.2592</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.7710</td>
</tr>
<tr>
<td>31</td>
<td>0.15564</td>
<td>0.79063</td>
<td>1.00000</td>
<td>0.72450</td>
<td>-0.10001</td>
<td></td>
</tr>
<tr>
<td>People</td>
<td>0.3950</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.5860</td>
</tr>
<tr>
<td>32</td>
<td>0.06698</td>
<td>0.68667</td>
<td>0.66443</td>
<td>0.72450</td>
<td>1.00000</td>
<td>-0.03092</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>0.7157</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.8666</td>
</tr>
<tr>
<td>32</td>
<td>0.47906</td>
<td>0.18294</td>
<td>&lt;0.0544</td>
<td>-0.10001</td>
<td>-0.03092</td>
<td>1.00000</td>
</tr>
<tr>
<td>Goals</td>
<td>0.0055</td>
<td>0.3162</td>
<td>0.7710</td>
<td>0.5860</td>
<td>0.8666</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>0.47906</td>
<td>0.18294</td>
<td>&lt;0.0544</td>
<td>-0.10001</td>
<td>-0.03092</td>
<td>1.00000</td>
</tr>
</tbody>
</table>
Table 5. Comparison of digital maturity level (Q4) with reduced hourly work week schedule (Q15).

<table>
<thead>
<tr>
<th>Q4 (Which Digital Maturity Level Best Describes Your Current Organization?)</th>
<th>Q15n</th>
<th>Frequency</th>
<th>Row Pct</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper–based 2</td>
<td>2</td>
<td>25.00</td>
<td>6</td>
<td>75.00</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Spreadsheet 1</td>
<td>1</td>
<td>16.67</td>
<td>5</td>
<td>83.33</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Commercial or customized quality IT solutions 1</td>
<td>1</td>
<td>14.29</td>
<td>6</td>
<td>85.71</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Product Lifecycle Management software ((i.e., Oracle Fusion Cloud Product Lifecycle Management) integrated 2</td>
<td>2</td>
<td>18.18</td>
<td>9</td>
<td>81.82</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Highest level of digital maturity 0</td>
<td>0</td>
<td>0.00</td>
<td>3</td>
<td>100.00</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total 6</td>
<td>29</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6 displays the relationship between the productive organizational learning type and responsible autonomy. A total of 31 manufacturers out of 35 responded to Questions 11 and 21. A total of 19 of 31 or 61% of responses were in the affirmative to describing the type of organizational learning that is or would be completed, as well as engaging in responsible autonomy with employees and teams to achieve specific goals.

Table 6. Comparison of productive learning type (Q11) to responsible autonomy (Q21).

| Q11 (Productive Organizational Learning Has Three Classifications. Which Classification Best Describes the Level of Productive Organizational Learning in Your Work Organization?) | Q21 (How Likely Is Your Organization Defined as Engaging in Responsible Autonomy with Employees and Teams to Achieve Specific Goals?) | Frequency | Row Pct | 1 = Extremely Unlikely | 2 = Somewhat Unlikely | 3 = Neither Likely nor Unlikely | 4 = Somewhat Likely | 5 = Extremely Likely |
|---|---|---|---|---|---|---|---|---|---|
| organizational inquiry that improves the way tasks are solved | 1 | 3 | 1 | 5 | 3 | 13 |
| inquiry in which the organization explores and restructures values | 7.69 | 23.08 | 7.69 | 38.46 | 23.08 | 13 |
| inquiry that betters the organizational learning of both types 1 and 2 | 33.33 | 33.33 | 33.33 | 0.00 | 0.00 | 3 |
| Total | 2 | 1 | 1 | 8 | 3 | 15 |
| 13.33 | 6.67 | 6.67 | 53.33 | 20.00 | 6 | 31 |
| Frequency Missing = 4 |

Scheme 1 represents a scatter plot comparison of the socio-technical design techniques of responsible autonomy and organizational learning for the manufacturing firms surveyed. The socio-technical design technique of responsible autonomy is on the x-axis and a culture of organizational learning is on the y-axis. The three lines are the simple linear regressions for small, medium, and large companies. The linear regression highlights the positive slopes for small- and medium-sized businesses, indicating that, as the culture of organizational learning increases in development, responsible autonomy is increasingly observed within the work organization.

Scheme 2 represents a scatter plot comparison of the socio-technical design techniques of a reduced daily work hour goal and a culture of organizational learning for the manufacturing firms surveyed. The socio-technical design technique of developing a culture of organization learning is on the x-axis and a reduced daily work hour goal is on the y-axis. The three lines are the simple linear regressions for small, medium, and large companies.
companies. The linear regression highlights a slightly positive slope for medium-sized businesses, indicating that, as an increase in the reduced work goal is achieved a culture of organizational learning is increasingly observed within the work organization.

![Scheme 1](image1.png)

**Scheme 1.** Q21 responsible autonomy in comparison to Q22 organizational learning.

![Scheme 2](image2.png)

**Scheme 2.** Q22 organizational learning compared to Q13 reduced daily work hour goal.
Scheme 3 represents a scatter plot comparison of the socio-technical design techniques of responsible autonomy and the promotion of productivity and innovation for the manufacturing firms surveyed. The socio-technical design technique of engaging in responsible autonomy is on the x-axis and the promotion of productivity and innovation are on the y-axis. The three lines are the simple linear regressions for small, medium, and large companies. The linear regression highlights a positive slope for small businesses, indicating that, as an increase in the promotion of productivity and innovation of teams while minimizing conflicts is achieved increased responsible autonomy with employees and teams is observed within the work organization.

Scheme 3. Q21 responsible autonomy compared to Q9 on productivity and innovation.

5. Discussion

In reference to the simple frequency chart outcomes described in the results section the following assumptions are made of the total surveyed population. Aggregately, very few manufacturers are utilizing decision support or judgment substitution through learning algorithms from various applications. Two out of the thirty-five manufacturers surveyed that utilize information technology solutions in the workplace were likely to establish a reduced daily work schedule. Nearly 94% of manufacturers responded affirmatively to continuously improving communication across departments and teams to instill employee engagement. However, less than half of manufacturers surveyed were leveraging a socio-technical organizational design framework to guide the flow of information and communication, which is described as data gathering, analysis and interpretation, summarizing the findings, testing the results with stakeholders, and iterating and amending as necessary to communicate recommendations to employees and stakeholders. Socio-technical design is critical to predictive work, such as productivity planning and labor scheduling. These communication strategies are essential to successful Industry 4.0 implementation.

Techniques that contribute to understanding the interrelatedness of social and technical factors of the organization, such as with the development of cross-functional diagrams, were being evaluated by 40% of the businesses. The promotion of productivity and innovation was reported to occur in 68.57% of respondents across all business sizes. From the work task perspective, examples from corporations, such as Google, illustrate a 20% policy,
where employees engage in personal projects that are innovative in nature during one-fifth of their work hours. Results of this flexible working arrangement have been products, such as Gmail, Google News, and Adsense [24]. In addition, 3M encourages a 15% culture where employees are encouraged to establish time to pursue innovative ideas. The experimentation may include new technology, process improvement, and team forming to support emerging trends. Innovations such as the Multilayer Optical Film, Cubitron, Abrasive Grains, Emphaze, AEX Hybrid Purifier, APC Flash-Free Adhesive, and Post-It Notes have been created in this manner [49].

Sixty percent of the manufacturers were leveraging a bottom-up problem-solving approach, yet slightly over sixty-two percent of employers rather than employees are leading the effort of specifying roles, responsibilities, and/or tasks that are specific to a job when optimizing or streamlining a process. In response to being asked whether they support the allocation of resources and work to change and improve production practices, organize work tasks, and strengthen internal cooperation, only 68.57% responded in the affirmative, which indicates that there are significant gaps in the needed resources for continuous growth and this will be observed in specific correlations addressed in this section.

In reference to Table 1, the small manufacturers surveyed in Minnesota and North Dakota reported that with regards to Q22 on organizational learning, significant gaps in technical knowledge acquisition exist as the correlations between this question and the technology socio-technical construct were insignificant. The Q13 reduced daily work hour goal corresponded significantly only to the technology socio-technical construct. When assessed independently, Q13 did not correspond significantly with Q18, Q20, Q21, or Q22. Also, with an alpha of 0.05, Q21 on responsible autonomy and Q9 on the promotion of productivity and innovation did not significantly correlate. In addition, Q22 on organizational learning and Q21 on responsible autonomy did not significantly correlate.

In reference to Table 2, the responses from medium-sized manufacturers surveyed in Minnesota and North Dakota indicate that there is no significant correlation between organizational learning and a reduced daily work hour goal. A significant correlation was not identified between Q21 on responsible autonomy and Q9 on the promotion of productivity and innovation. In addition, a significant correlation was not identified between Q22 on organizational learning and Q21 on responsible autonomy.

In reference to Table 3, the responses from large-sized manufacturers surveyed in Minnesota and North Dakota indicate that there is no correlation between Q22 on organizational learning and Q13 on establishing a reduced daily work hour goal to serve to jointly optimize the technical and human factors of an organization to achieve higher productivity and employee wellbeing. A significant correlation was not identified between Q22 organizational learning and Q21 responsible autonomy. In addition, a significant correlation was not identified between Q21 responsible autonomy and Q9 the promotion of productivity and innovation.

These outcomes answer the first research question: organizational learning is not significantly correlated with a reduced daily work hour goal among manufacturers in Minnesota and North Dakota. In reference to Table 6, the correlation between responsible autonomy (Q21) and a culture of organizational learning (Q22) was not observed as significantly positive. However, the cross comparison of productive organizational learning (Q11) and responsible autonomy (Q21) illustrated that 61% of responses reported focusing on organizational learning as well as engaging in responsible autonomy with employees to achieve specific goals. The difference between Q22 and Q11 is that Q22 suggests full implementation of organizational learning within the culture where the process is observed as continuous.

These outcomes also answer the second research question focused on whether a positive correlation between responsible autonomy and the promotion of productivity and innovation would be observed. Responsible autonomy did not show a strong positive
correlation with the promotion of productivity and innovation (Q9) with the manufacturers surveyed.

The third research question focused on whether a positive correlation between responsible autonomy and organizational learning among regional manufacturers would be observed. There was no significant correlation observed between responsible autonomy and organizational learning among small, medium, and large regional manufacturers. These outcomes answer the third research question: responsible autonomy does not significantly correlate to a culture of organizational learning among regional manufacturers.

This survey was based on the socio-technical framework developed by Davis et al. This socio-technical framework identifies the social factors of an organization as people, goals, and culture and the technical factors of infrastructure, technology and processes as interdependent. These elements operate within an external environment that offers unique economic conditions, diverse stakeholders, and regulation. The theoretical insights of various academic researchers cited previously contributed to the alignment of a new assessment. This study is a unique approach to analyzing the socio-technical design maturity of manufacturers in Minnesota and North Dakota when considering the implementation of reduced daily work hour goals. Critical success factors pertaining to leadership, responsible autonomy, organizational learning, and communication have been recommended by academic researchers and practitioners when leading organizations towards a modern work environment. The results of the second survey validate the results of the first survey by the authors. The first survey and paper provide a useful tool for assessing socio-technical competence management within an organization when jointly optimizing social and technical factors of an organization \[50\]. The second survey tool as a standalone assessment, as well as in combination with the first survey tool, may serve the purpose of checking the sustainability status of small, medium, and large manufacturers as organizations digitally transform to offer flexible work arrangements for employees. This survey illustrates an emerging management approach with SMEs in supporting continuous improvement efforts.

6. Conclusions

The six socio-technical constructs of this study described how current organizational design practices contribute to supporting organizational learning, responsible autonomy, and promoting productivity and innovation to achieve reduced daily work hour goals among small, medium, and large manufacturers. A survey was conducted to provide a timely in-depth analysis of socio-technical design techniques that the cited academic researchers have reported contribute to successfully achieving new ways of working. This research adds to the socio-technical literature by assessing the current socio-technical design practices within the context of manufacturers in Minnesota and North Dakota. The study promotes socio-technical practice by highlighting critical socio-technical factors advancing the successful adoption of digital transformation strategies and reduced work week schedules.

Strategic planning is critical to the success of digital transformation. Led by employees, barriers, challenges, and opportunities to providing employees with reduced daily work hours are identified and solved in a bottom-up leadership methodology. In reference to the third research question, responsible autonomy is intrinsic to the successful implementation of job crafting in the Industry 4.0 context, as it contributes to a productive organizational culture of learning and productive behavior \[28]\.

Job demands require that the needed resources are allocated to workers to reduce the incidence of burnout \[31\]. A method of avoiding conflicts and failed projects is through engagement with those employees completing the tasks involved with high levels of productivity and innovation. Trust is a key factor in the relationship between employees and managers to support these endeavors \[18\]. Addressing the second research question, employee engagement through the fostering of responsible autonomy is essential to attaining a joint optimization of socio-technical factors.
Leadership vision must be informed by the possible growth opportunities available with the adoption of the new communication and information technologies of Industry 4.0 [51]. Digital leadership encourages new methods of organizing and communicating. This leadership trait supports employee autonomy, innovation, and creativity through supporting employee job crafting, which is an employee-led job design strategy. Key digital leadership skills are a bottom-up organizational change strategy, a future-oriented vision, digital literacy, and adaptability [52]. A key example of organizational change driven by digital leadership is through the development of cross-functional teams, which aids with the dispersion of communication throughout an organization, heightening the level of organizational learning [39]. Reduced work week goals are achievable through continuous joint optimization of socio-technical components, such as integrating a culture of organizational learning, which is integral to the first research question.

This study’s limitations are the small sample size of regional manufacturers that were assessed and the fact that some manufacturers were not utilizing Industry 4.0. Therefore, these companies were not benefitting from its advantages.

In addition, few companies are embracing reduced work week schedules or flexible work arrangements in the manufacturing industry in Minnesota and North Dakota. A reason for the regional inattention to this long-term sustainability goal may be a perceived lack of benefit for its intended workforce and to the organization as a whole. Outreach and training on the benefits of socio-technical design and its deployment methodologies are needed to prepare manufacturers for newly adopting Industry 4.0. In addition, those organizations currently employing Industry 4.0 technologies will benefit from the predictive attributes of successful socio-technical design practices.

Future research can build on our study by assessing Industry 4.0 technologies currently used among manufacturers in Minnesota and North Dakota. In addition, further understanding of the current maturity level of digital transformation and the commitment to socio-technical design techniques among regional manufacturers of all sizes aids in determining the opportunities for and challenges to realizing the long-term sustainability initiative of reduced daily work hour schedules.

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**Appendix A. Survey Questions**

Socio-technical construct: Technology

The fourth question was “Which digital maturity level best describes your current organization?” The five options for answers provided were paper-based; spreadsheet; commercial or customized quality IT solutions; product lifecycle management software integrated; and closed-loop manufacturing, closed-loop quality data and product lifecycle management software integrated [7].

The sixteenth question was “How likely are employees to experience decision support through learning algorithms from various applications? (Employee autonomy and decision-making decisions are both impacted by learning algorithms in various IT applications. Algorithmic management can vary from decision support to judgment substitution for the employee. Learning algorithms shape the choices available to employees by automating
decision-making, specifically by imposing predefined rules and rapidly processing massive amounts of data.)” [48].

The seventeenth question was “In reference to the prior question, how likely are employees to experience judgment substitution for the employee through learning algorithms from various applications, such as software platforms, as an example?” [48].

Socio-technical construct: Processes

The fifth question was “How likely is your organization to follow an operational process that includes these steps: data gathering, analysis and interpretation, summarizing the findings, testing the results with stakeholder, and iterating and amending as necessary?” [5].

The sixth question was “How likely is your organization to create cross-functional diagrams, which are used to map the workflow of interrelated activities and resources (i.e., product, workers, machine, material, workstation set up, production line, factory operations, external factors, etc.) that transform inputs into outputs, as well as, to portray relationships among various resources performing actions?” [35].

The seventh question was “Which timeline(s) does your organization generate, that include(s) key factors leading up to the event or scenario analyzed, grouped by the six factors of goals, people, buildings/infrastructure, technology, culture, and processes/procedures?” [5]. The survey participants were provided with the options to select long-standing (3+ months), issues immediately preceding the event (0–3 months), factors involved on the day, and an option to provide an alternate response.

The twentieth question was “How likely is your organization to continuously improve communication across departments and teams to instill employee engagement?” [28].

The twenty-third question was “How likely is your organization to operate with standard operating procedures on work processes, systems architecture, and data formats?”

The twenty-fifth question was “How likely is your organization to recognize both technology and people dimensions to ensure that systems are highly efficient and contain better human characteristics that lead to better employee satisfaction?” [16].

Socio-technical culture: People

The tenth question was “How likely is your organization to specify roles, responsibilities, and/or tasks that are specific to that job when you are trying to optimize or streamline a process?”

The eighteenth question was “How likely is your organization to leverage a bottom-up problem solving approach? (i.e., Job crafting that focuses on co-workers deciding and designing together to improve their work and workplaces during change.)” [28].
The nineteenth question was “How likely is your organization to develop cross-functional teams?” [39].

The twenty-first question was “How likely is your organization defined as engaging in responsible autonomy with employees and teams to achieve specific goals? Responsible autonomy is defined as teams or groups having the discretion to judge and decide the organization, timing, and pace of work tasks, which entails a relaxation of direct management supervision and helps to avoid ‘silo thinking’ by engaging the entire system.” [16].

Socio-technical construct: Infrastructure

The twelfth question was “How likely is your organization to support allocation of resources and work to change and improve the production practices, organize work tasks, and strengthen internal cooperation?”

Socio-technical construct: Goals

The thirteenth question was “How likely will establishing a reduced daily work hour goal serve as a way to jointly optimize the technical and human factors of your organization to achieve higher productivity and employee wellbeing (i.e., such as a six-hour workday in place of an eight-hour workday)?” [18].

The fourteenth question was “Are flexible working hours applied in activities upstream or downstream of the production system? (i.e., design, protocelling, manufacturing, fabrication, testing, quality control, packaging, and shipping.)” [21]. A yes or no response was required. If a ‘yes’ response was provided, a follow-up question for additional specification was provided.

The fifteenth question was “Are hourly labor requirements and productivity goals achievable with a reduced hourly week schedule when considering organizational factors? (i.e., product-related or design-related factors, worker-related factors, material-related factors, factory operations-related factors, and production-line related factors).”

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