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SCUOLA DI INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE

Digitalization and Sustainability in the Supply Chain: A Gordian Knot?

TESI DI LAUREA MAGISTRALE IN MANAGEMENT ENGINEERING
INGEGNERIA GESTIONALE

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EXECUTIVE SUMMARY OF THE THESIS

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1. Introduction

Digitalization impacts supply chain sustainability both positively and negatively, as presented in previous research. This dissertation aims to clarify the relationship between digitalization and supply chain sustainability and the way digitalization can support supply chain sustainability. To reach these objectives, two research questions are formulated:

1. How can digitalization influence sustainability of supply chain?
2. What are the factors that can influence the relationship between digitalization and sustainability?

2. Literature Review

2.1. General Introduction of Digitalization

Digitalization is the adoption of digital or computer technology by an organization, industry, country, etc (OED Online, 2023a). Konle-Seidl & Danesi (2022) pinpoint three digitalization impacts on work and employment: work automation, process digitization and coordination by platforms. Successful digitalization execution requires consideration of these selected aspects, such as crucial role of top management (Ko et al., 2022), implementation design (Ghobakhloo & Iranmanesh, 2021), trained and supported users support (Masood & Egger, 2019), and selection of business partners (Aghimien et al., 2020).

2.2. General Introduction of Sustainability

Sustainability, derived from "sustainable", means capable of being maintained or continued at a certain rate or level (OED Online, 2023b). Elkington (1997), sustainability has three pillars: economic, environmental, and social.

1. Economic sustainability: production process which satisfies the present level of consumption without compromising future needs (M. A. Khan, 1995).
2. Environmental sustainability: preserving raw material sources for human needs and managing wastes without harming humans (Goodland, 1995).
3. Social sustainability: fair welfare distribution among contributors to the organization and its supply chain (Jeronen, 2013).

2.3. Systematic Literature Review

Table 1 shows the systematic literature review process. Shortlisted papers are read thoroughly to find supporting sentences for four pillars theoretical framework which are the positive and negative impacts of digitalization on sustainability, and the external and internal factors influencing both impacts. Gathered sentences with the same gist are clustered into representative words, forming the theoretical framework.

Table 1: Paper selection

Process description	No. articles
Search string: see Table 2.1 in dissertation	3,909 (S); 2,797 (W)
Inclusion criteria: Articles, Reviews; English	2,239 (S); 2,460 (W)
Subject area: see Figure 2.1 and Figure 2.2 in dissertation	2,194 (S); 1,840 (W)
Remove duplicates	1,164
Quality check: Q1 SCImago	537
Title & abstract check	158
Final shortlisted	72

2.3.1. Positive Impact of Digitalization on Sustainability

There are ten positive impacts of digitalization on sustainability which are:

1. Increasing process efficiency by making supply chain processes more flexible and responsive (Schilling & Seuring, 2023) which improves companies' productivity and competitiveness (Ghobakhloo et al., 2021; Sharma et al., 2022)
2. Enabling real-time operations and data-driven decision making which reduces uncertainty risk (Ghobakhloo, 2020) and allows communication efficiency (Ding, 2018).
3. Improving company's financial condition by decreasing production cost (Ghobakhloo, 2020; Sharma et al., 2022) and boosts profit (de Souza et al., 2021; Kittipanya-ngam & Tan, 2020).
4. Increasing resource usage efficiency by cutting consumption of energy (Ghobakhloo et al., 2022; Kamble et al., 2018), raw material and water (Oubrahim et al., 2023).
5. Reducing waste and emission (Ghobakhloo, 2020; Ghobakhloo et al., 2021, 2022; Kamble et al., 2018; Nayal et al., 2022; Oubrahim et al., 2023)
6. Improving employment condition and development by strengthening employees' skills and well-being (I. S. Khan et al., 2021), and workplace safety (Ghobakhloo et al., 2022; Nantee & Sureeyatanapas, 2021).
7. Enabling process transparency by increasing visibility, traceability, and transparency of the supply chain (Ghobakhloo et al., 2022)
8. Enabling compliance monitoring through tracking production and distribution processes (Kshetri, 2021)
9. Enabling community empowerment through enhancement of community's living standards and well-being (Kshetri, 2021)
10. Enabling better product and service provision to customers through customer-oriented strategies (Ghobakhloo et al., 2021)

2.3.2. Negative Impact of Digitalization on Sustainability

There are five negative impacts of digitalization on sustainability which are:

1. High implementation cost (Nantee & Sureeyatanapas, 2021)
2. Overconsumption of energy (Pakseresht et al., 2023), electricity (Nantee & Sureeyatanapas, 2021), and natural resources (Ghobakhloo et al., 2021)
3. Increase waste and pollution (Ahmadova et al., 2022; Kunkel et al., 2022)
4. Reduce employment due to replacement with technology (Beltrami et al., 2021; Ding, 2018)
5. Information exposure related to privacy (Beltrami et al., 2021) and sensitive information (Dwivedi & Paul, 2022)

2.3.3. Internal Contingencies on the Relationship

There are six internal contingencies on the relationship which are:

1. Management vision through commitment (Gupta & Singh, 2021; Schilling & Seuring, 2023; Vafadarnikjoo et al., 2021), strategies (Beier et al., 2022; Luthra et al., 2020), and business policies alignment with sustainability (Seddigh et al., 2022)
2. Human capital readiness by providing training (Beltrami et al., 2021; Dongfang et al., 2022; Jayashree et al., 2022; Kazancoglu et al., 2021; Ozkan-Ozen et al., 2022)
3. Infrastructure readiness (Gupta & Singh, 2021)
4. Collaboration and integration between suppliers, other stakeholders and customers (Kittipanya-ngam & Tan, 2020; Kunkel et al., 2022; Luthra et al., 2020; Oubrahim et al., 2023)
5. Implementation strategy to evaluate suitable operations technology (Chaouni Benabdellah et al., 2023; Torres da Rocha et al., 2022)
6. Reliable data (Chaouni Benabdellah et al., 2023; Seddigh et al., 2022)

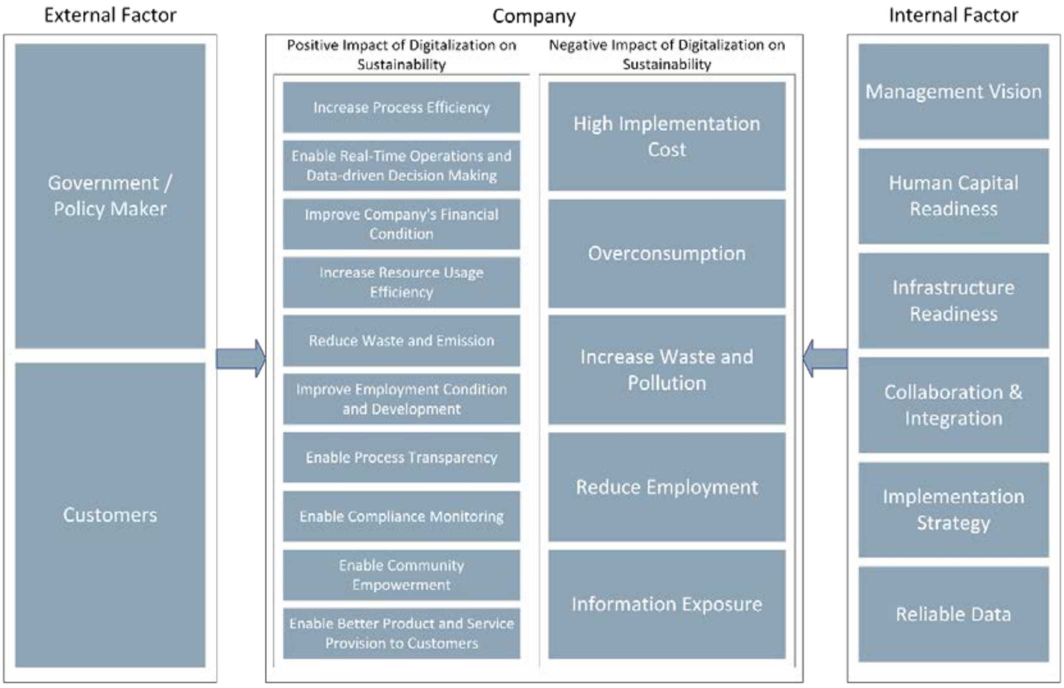

Figure 1: Theoretical framework of digitalization and sustainability in supply chain

2.3.4. External Contingencies on the Relationship

Government and customers are two external contingencies on the relationship. Government supports through policies (Kumar et al., 2022), regulations and incentives (Beier et al., 2022), while customers can put pressure to company to adopt green solutions (Gupta & Singh, 2021).

Based on previous findings from reviewed papers, a theoretical framework is proposed in Figure 1.

3. Research Design

To verify the theoretical framework, case study research is conducted to exploit insights from small number of cases (Yin, 2018). To ensure the validity, reliability, and quality of the research, data triangulation is adopted through semi-structured interview and documentation. Interviews with case companies' top-level management in supply chain or production, and in business transformation or innovation are guided by these questions:

1. How is the supply chain process of the product working from initial stage to the final stage?
2. Is there any digitalization implemented in this step of the supply chain process? How is digitalization being implemented?
3. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?
4. What and how are the factors that lead to the successful implementation of this digitalization?
5. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?
6. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?
7. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?
8. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

Documentations involves collecting public information like annual reports, official websites, YouTube videos, and internal documents of case companies. Cross checking between these sources enhances data validity (McCutcheon & Meredith, 1993; Yin, 2018).

In case selection, there are several criterions to ensure generalization of case study's findings (external validity) and repeatability of the studies with the same result (reliability) (Yin, 2018).

1. The manufacturing industry is chosen for its adoption of digitalization and extensive research

on this specific industry in the current dissertation's systematic literature review.
2. All case companies are based in Indonesia, a global manufacturing leader ranked 12th in output (World Bank, 2022).
3. Manufacturing companies are part of five prioritized sectors of Indonesian government program to accelerate Industry 4.0 technology implementation.
4. Various product types in different cases enable observation of digitalization implications on supply chain sustainability.
5. Different company size in the case studies allows discovery of different key internal and external factors, while also challenges and opportunities of digitalization in the supply chain (Kittipanya-ngam & Tan, 2020).

Table 2 shows the details of each case.

Table 2: Case details

Product	Informants
Ice Cream (IC)	1. PM Excellence & OEE Improvement Assistant Manager 2. Assistant Engineering Manager for Electrical & Digitalization
Powdered Beverage (PB)	1. Business Analyst Manager 2. Production Manager 3. Former Digital Transformation Manager
Instant Noodle (IN)	1. Manufacturing General Manager, System Development Analyst, Central PPIC Manager 2. System Development Analyst, Factory Manager
Personal & Fabric Care (PFC)	1. Senior Plant IT Manager 2. IT Distributor Operation Manager

Eisenhardt (1989) suggests that with-in case analysis unveils each case's individual patterns, while cross-case analysis compares between cases to identify similarities or differences which can lead to new findings. To do with-in case analysis, key information to be considered are:

1. Positive implications of digitalization implementation on supply chain sustainability.
2. Negative implications of digitalization implementation on supply chain sustainability.
3. Internal contingencies that influence the relationship between digitalization and supply chain sustainability.
4. External contingencies that influence the relationship between digitalization and supply chain sustainability.

After gathering key information, cross-case analysis is conducted to identify similar or different patterns between cases (Eisenhardt, 1989). Then, the results are cross checked with the theoretical framework (Figure 1) to verify existing framework.

4. Case Studies and Discussion

The findings from the four case studies in the with-in case analysis are summarized in Table 3. The following discussions cover positive and negative impacts of digitalization on sustainability, and internal and external contingencies.

4.1. Positive Impacts of Digitalization on Sustainability

The discussion is conducted individually for each case company due to their technological variations.

4.1.1. Ice Cream Company

The company adopts web-based applications to replace paper-based processes for tasks like permit to work (PTW), emergency work order (EWO), and maintenance management, leading to reduced paper waste, reduced overtime budget through PTW, enhanced transparency in tracking spare part usage, simplified issue investigations and eliminated non-value-added tasks. PowerBI dashboards encourage innovation, help identify areas to be improved and simplify data extraction and processing. PLC application in machinery control also reduces electricity consumption, while remote control of cooler enables remote and real-time monitoring.

4.1.2. Powdered Beverage Company

The company employs several technologies, such as tender submission platform which centralizes procurement management, and in-house weighing application which eliminates human error in manual weighing. Integration between ERP systems and related applications like Warehouse Management System (WMS) streamlines business processes, provides valid and real-time data, reduces paper waste and cuts cost, aligning with Oubrahim et al. (2023). Additionally, manufacturing execution system (MES) streamlines manufacturing processes, enhances process transparency and real-time data access, consistent with Ding (2018) and Nayal et al. (2022). Besides, Robotic Process Automation (RPA) removes repetitive tasks and enhances productivity. These digital innovations encourage employees to learn about technology.

Table 3: A summary of within case analysis

	Ice Cream Company	Powdered Beverage Company	Instant Noodle Company	Personal & Fabric Care Company
Technologies	1. Web-based applications 2. PowerBI dashboards 3. Programmable Logic Controller 4. Remote control of ice cream cooler	1. Supplier's documents submission web platform 2. Integration between ERP system, WMS, and other applications 3. Manufacturing Execution System 4. Robotic Processing Automation	1. Truck Queueing System (TQS) 2. E-Purchasing Monitoring (EPM) 3. Integration between ERP system, TQS, and EPM 4. Auto-recording and digital approval in ERP system 5. Automatic daily report	1. Supplier's documents submission web platform 2. Process Control Strategy in raw material suppliers 3. Industrial control system using Purdue Model 4. Excel and PowerBI for truck monitoring 5. Autonomous Intelligent Vehicle (AIV) 6. Warehouse Management System (WMS) 7. Dynamic Routing System (DRS) 8. Integration of WMS, DRS, and distributors' ERP systems 9. Python-based RPA
Internal Contingencies	1. Global headquarters directives 2. Internal collaboration between the company's plants 3. Infrastructure readiness	**1.** Top management **2.** Strategic plans with specific objectives 3. Innovation as work culture	1. Top management 2. Careful annual plan 3. Sequential project approval process	1. Regional headquarter and top management 2. Culture of knowledge sharing and innovation 3. Rewards and recognition 4. Ideas from soft floor workers
External Contingencies	1. Competitors 2. Regulatory bodies	1. External technology development 2. Government 3. Customer shopping habit 4. Foreign agency entity	1. External vendors 2. Technological fairs	1. Innovative external solutions 2. Competitors 3. Business partners (distributors and raw material suppliers) 4. Regulatory bodies 5. Customer feedback
Negative Impacts of Digitalization on Sustainability	1. Increased waste and overconsumption during first installation of new machines 2. Substantial upfront investment for digitalization	1. High cost of development 2. Reduce manpower 3. Reduce critical thinking 4. Temporary decrease in production output due to transitional stage	1. Initial high investment cost 2. Reduce employment	1. High implementation cost 2. Reduce human resources 3. Generate NPI and bad environmental impacts due to initial adjustments of integration between WMS, DRS, and distributors' ERP systems

Positive Impacts of Digitalization on Sustainability	1. Eliminate non-value-added activities 2. Reduce overtime budget 3. Reduce lost spare part and enable the spare part usage tracking 4. Remote monitoring 5. Prolong lifespan of documentation 6. Simplify investigations in case of issues 7. Encourage employees to make improvements 8. Ease identification of production workstation to be improved 9. Reduce electricity consumption	1. Have access to more valid and real time data 2. Improve productivity 3. Reduce costs 4. Encourage eagerness of employees to learn about technologies 5. Reduce paper usage **6.** Reduce pollution and fuel costs	1. Enable remote and real-time monitoring 2. Enhance the process evaluation for faster decision making 3. Ease identification of areas to be improved 4. Ease process improvement, better efficiency, reduced waste, and increased production outputs 5. Minimize human error 6. Securely store data on the server 7. Paperless operations 8. Improve productivity 9. Simplify data analysis and processing 10. Better communication among departments 11. Encourage young employees in digitalization	1. Reduce costs 2. Reduce paper costs and minimize data loss risks related to paper-based records 3. Have more efficient electricity usage, leading to reduced utility cost and waste. 4. Reduce waste and improve material utilization 5. Eliminate manual tasks 6. Have access to more valid and real time data 7. Reduce pollution and fuel costs 8. Have better well-being for employees and fostering more ideas 9. Transfer new skills to local firms

4.1.3. Instant Noodle Company

The company employs in-house applications like truck queueing system (TQS) for remote and real-time monitoring of truck movements, and e-purchase monitoring (EPM) which centralizes procurement management for non-group vendors. Auto-recording and digital approval of SAP ERP system reduce paper waste, allow real-time data access, and increase process efficiency by removing human error in previous paper recording. Integration between ERP, TQS and EPM enhances process efficiency, real-time data access, and inter-department communication, in line with Ding (2018). Automatic daily reports also increase process efficiency and employment condition by removing repetitive data processing tasks and enhancing meeting effectiveness. These digital innovations have encouraged young employees to chip in company's digitalization efforts.

4.1.4. Personal and Fabric Care Company

The company employs many technologies, such as material certification upload platform for suppliers, removing individual certificate checks, and MES in production lines, reducing paper waste and simplifying data extraction and processing. Process Control Strategy (PCS) assistance to suppliers improves resources efficiency and empowers domestic suppliers. PowerBI and Excel in truck monitoring ensures plant's security compliance. In the warehouse, Automated Intelligence Vehicle reduces manual handling, while the WMS efficiently assigns nearby picking workers. Dynamic Routing System (DRS) optimizes delivery routes and ensures sustainable operations, aligning with Kunkel et al. (2022). Integration between WMS, DRS and distributors' ERPs streamlines processes and enables real-time operations. Python-based RPA removes manual checks and data entry, while also hones employees' programming skills. These digital improvements enhance employees' well-being and creativity, aligned with I. S. Khan et al. (2021) and Oubrahim et al. (2023).

4.2. Negative Impacts of Digitalization on Sustainability

High implementation cost of digitalization is acknowledged by all case companies, consistent with findings of Nantee & Sureeyatanapas (2021). To address this, the companies align digital tools with problems and conduct cost-benefit analysis.

Unavoidable overconsumption and increased waste also occurred during early stages of digital tool adoptions in the IC company and the PFC company. Contrary to findings of Nantee & Sureeyatanapas (2021), surge in electricity consumption did not apply in the cases, except for the PB company. However, the economic benefit still outweighs the electricity costs.

Reduced employment due to automation, including RPA in the PB company and WMS in the PFC company, has eliminated repetitive works, but also replaced human roles. To address this, the companies transfer affected employees to other departments, and apply strategies like dedicating certain processes to non-permanent workers in the PB company. However, information exposure issues did not appear in cases.

Besides the drawbacks mentioned in the reviewed literature, the PB company faced reduced critical thinking and an inevitable temporary decrease in production output due to transitional stage. To counter the issues, the company organizes an annual innovation showcase to trigger employees' ideas.

4.3. Internal Contingencies

Top management holds pivotal role in securing company's economic sustainability due to digitalization by aligning digital solutions with problems, conducting cost-benefit analysis, annual planning, and ensuring proper execution through effective leadership of each supply chain section leader. This is consistent with Chaouni Benabdellah et al. (2023) and Torres da Rocha et al. (2022).

Work culture affects the digitalization journey of the case companies, including internal and external collaboration, and innovation. Sharing sessions between plants in the IC and the PFC company is an example of internal collaboration, in line with Benzidia et al. (2021). External collaboration includes PFC company's assistance to raw material suppliers in PCS project and integration with distributors' ERP systems are aligned with Bag et al. (2020), Tseng et al. (2022), and Oubrahim et al. (2023). Another example is assistance from Ministry of Industry and GIZ, a German international development agency by providing training and guidance in the PB company's digitalization journey, as noted by Niehoff et al. (2022). Fostering innovation is evident in daily stand-up meetings in the PFC company and innovation showcase event in the PB company.

To prepare both human resources and infrastructure, digital awareness training in the PB company and having standby developers in babysitting period during the implementation among the cases are examples of efforts to mitigate employees' reluctance during the implementation, in line with Hassoun et al. (2022). Aligning digital solutions with problems and assessing system's robustness and its hardware units are unavoidable efforts to ensure infrastructure readiness, consistent with Jayashree et al. (2022).

Although not explicitly mentioned, the case companies recognize the importance of data reliability, enabling them to identify areas to be improved and expedite decision making, in line with Seddigh et al. (2022) and Chaouni Benabdellah et al. (2023).

4.4. External Contingencies

Government involvement is illustrated in the PB company case, providing training and consultancy in cooperation with GIZ. This corresponds with Zhong et al. (2017) and Kunkel et al. (2022). Moreover, the Indonesian government offers fiscal incentives to companies partnering with vocational school and establishing R&D centers (Ministry of Industry Republic of Indonesia, 2019), as documented in prior studies (Beier et al., 2022; Bressanelli et al., 2021; Dongfang et al., 2022; Yu et al., 2022). It is important to note that proactively maintaining network with these industry stakeholders is essential to access government support, as seen in the PB company case.

However, there is no direct pressure from customers in the case companies to adopt digital tools or green initiatives, which differs from Gupta & Singh (2021) and S. A. R. Khan et al. (2022). In the case companies, customers indirectly influence digitalization journey, including product complaints in the PFC company and shift to online shopping habits in the PB company.

Beyond the mentioned external factors, the case study research reveals that business partners (raw material suppliers, distributors, and technology vendors) contribute to the company's digitalization journey. For example, the PFC company assisted its suppliers in implementing process control strategy and urged distributors to integrate their ERP systems with the company's system. Similarly, the IN company pushes non-group transportation vendors to adopt GPS for tracking delivery truck movements. Furthermore, technology vendors contribute by keeping the case companies updated about technology developments, as seen in the case of IN company and PB company.

The study also reveals that regulatory bodies like Indonesia National Agency of Drug and Food Control and Bureau Veritas indirectly promote document digitization, as shown in the IC company case. International development agencies such as GIZ support the digitalization journey, as exemplified in the PB company case. Lastly, benchmarking competitors despite the limited data availability helps them stay updated about technology trends, as evidenced by IC company and PFC company.

4.5. Framework Refinement & Enrichment

The case studies unveil new benefits which are secure data storage on servers and reduced data loss risk linked to paper records, adding new positive impact of "Extend document lifespan and reduce data loss risk".

There are also new findings about drawbacks specific to the PB company, including a temporary decrease in production output due to transitional stage and reduced critical thinking due to a potential over reliance on technology. Since reduced critical thinking is associated with employment conditions, it merges with "Reduce Employment", renamed as "Reduce Employment Condition". The decrease in production output is temporary and can be disregarded.

Concerning the internal contingencies, the case studies reveal that collaboration and integration are an integral part of the work culture of these companies alongside the culture of innovation in the PB company and the PFC company. To encompass these work cultures and other specific work culture practices, "Collaboration & Integration" is reframed as "Work Culture". Human capital and infrastructure readiness are interdependent essential for successful digitalization, as shown in the case companies. Given this interdependence, both factors are unified under "Resource (Human & Infrastructure) Readiness" since they must progress simultaneously.

In terms of external contingencies, the case studies find that business partners are involved in digitalization journey, as evidenced in the case of the PFC company, the IN company, and the PB company. These examples can be collectively categorized as "Business Partners". Meanwhile, influence of regulatory bodies in the IC company, GIZ involvement in the PB company, and competitors as benchmarks for companies can be categorized as new external factors: "Regulatory Bodies", "International Agencies", and "Competitors".

These new insights will be incorporated into the framework of Figure 2.

5. Conclusions

The study revealed that top management secures the company's economic sustainability in digitalization journey by aligning technology with problems, cost-benefit analysis, planning, and executing through its supply chain leaders. Work culture indirectly benefits employees and community socially and environmentally. Government initiatives support companies' economic sustainability and employees' skill development. Company relationships with business partners also create social benefits for both parties. To address negative impacts of digitalization on sustainability, companies implicitly mitigate, starting from company's economic condition, then employee impacts, and finally environmental issues.

This research offers managers with a practical map for understanding digitalization impacts, considering internal and external contingencies (Figure 2). The experiences from each case company can provide insights of potential challenges and effective mitigation practices. From an academic perspective, this research enhances understanding of the relationship between digitalization and supply chain sustainability.

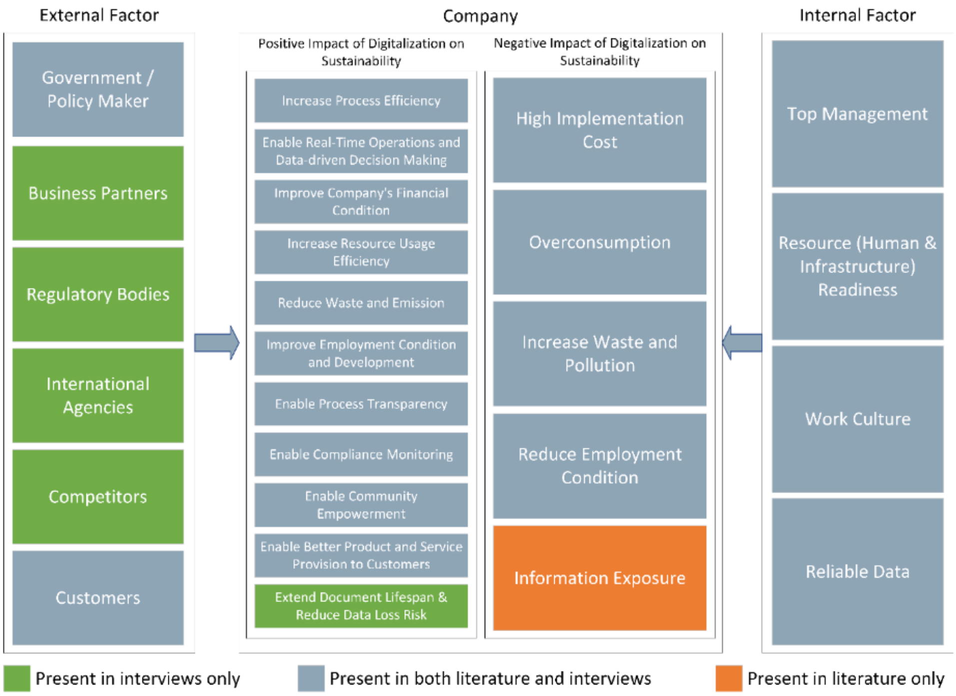

Figure 2: Framework of digitalization and sustainability in supply chain.

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Abstract

In supply chain operations, digitalization has affected its sustainability. Some research indicated positive impacts, but others found the opposite. This dissertation is aimed to clarify the interplay between digitalization and sustainability in the supply chain, and how digitalization can support supply chain sustainability. This study began with a systematic literature review on the sustainability impact of digitalization in the supply chain, identifying both positive and negative examples, and internal and external contingencies that influence the relationship. A theoretical framework was constructed from this literature review. To verify the framework, case studies were conducted in four Indonesian FMCG companies. The findings unveiled eleven clusters of positive impacts which can be outlined to operational efficiency (efficient and compliant process, real-time and transparent operations, waste reduction, and better product and service provision), financial performance (improved financial condition, and efficient resource usage), and social impact (enhanced employment condition and community empowerment). Conversely, five clusters of negative impacts were high costs, overconsumption, increased waste, job losses, and information exposure. It also identified four internal factors (top management, resource readiness, work culture, and reliable data) and six external factors (government, business partners, regulatory bodies, international agencies, competitors, and customers) that influence the relationship between digitalization and supply chain sustainability. Further, the study revealed that top management secures the company's economic sustainability in digitalization journey by aligning technology with problems, analyzing costs and benefits, planning, and executing through its supply chain leaders. Work culture indirectly benefits employees and community, both socially and environmentally. Government initiative supports companies' economic sustainability and promotes employees' skill development. Company's relationships with business partners also create social benefits for both parties. Moreover, in addressing negative impacts of digitalization on sustainability, companies organize the mitigation, starting from economic condition of the company, then employee impacts, and finally environmental issues. These findings contributed to the theoretical framework, offering practical guidance for managers, and providing better understanding of the relationship between digitalization and supply chain sustainability.

Key-words: digital, digitalization, sustainability, supply chain, supply chain digitalization, manufacturing, triple bottom line.

Abstract in italiano

La digitalizzazione ha influenzato la sostenibilità delle operazioni della catena di approvvigionamento. Alcune ricerche hanno indicato impatti positivi, mentre altre hanno trovato il contrario. Questa tesi mira a chiarire l'interazione tra digitalizzazione e sostenibilità nella catena di approvvigionamento e come la digitalizzazione possa sostenere la sostenibilità della catena di approvvigionamento. Lo studio è iniziato con una revisione sistematica della letteratura sull'impatto della digitalizzazione sulla sostenibilità nella catena di approvvigionamento, identificando esempi positivi e negativi, e contingenze interne ed esterne che influenzano la relazione. È stato costruito un quadro teorico da questa revisione della letteratura. Per verificare il quadro, sono stati condotti studi di caso in quattro aziende indonesiane del settore FMCG. Le scoperte hanno rivelato undici gruppi di impatti positivi che possono essere delineati per l'efficienza operativa (processi efficienti e conformi, operazioni in tempo reale e trasparenti, riduzione degli sprechi e migliore fornitura di prodotti e servizi), i prestazioni finanziaria (miglioramento delle condizioni finanziarie e uso efficiente delle risorse) e l'impatto sociale (miglioramento delle condizioni di impiego e potenziamento della comunità). Al contrario, cinque gruppi di impatti negativi sono stati costi elevati, sovraconsumo, aumento dei rifiuti, perdita di posti di lavoro e esposizione delle informazioni. La ricerca ha anche identificato quattro fattori interni (alta direzione, prontezza delle risorse, cultura aziendale e dati affidabili) e sei fattori esterni (governo, partner commerciali, organi di regolamentazione, agenzie internazionali, concorrenti e clienti) che influenzano la relazione tra digitalizzazione e sostenibilità della catena di approvvigionamento. Inoltre, lo studio ha rivelato che la alta direzione garantisce la sostenibilità economica dell'azienda nel percorso di digitalizzazione allineando la tecnologia ai problemi, analizzando costi e benefici, pianificando ed eseguendo attraverso i leader della catena di approvvigionamento. La cultura aziendale beneficia indirettamente i dipendenti e comunità, sia socialmente che ambientalmente. L'iniziativa governativa sostiene la sostenibilità economica delle aziende e promuove lo sviluppo delle competenze dei dipendenti. Le relazioni dell'azienda con i partner commerciali creano anche benefici sociali per entrambe le parti. Inoltre, per affrontare gli impatti negativi della digitalizzazione sulla sostenibilità, le aziende organizzano la mitigazione, iniziando dalle condizioni economiche dell'azienda, poi agli impatti sui dipendenti e infine alle problemi ambientali. Queste scoperte hanno contribuito al quadro teorico, offrendo guida pratiche per i dirigenti e una migliore comprensione della relazione tra digitalizzazione e sostenibilità della catena di approvvigionamento.

Parole chiave: digital, digitalizzazione, sostenibilità, catena di approvvigionamento, digitalizzazione della catena di approvvigionamento, manifatturiera, triplice approccio.

Contents

1 Introduction

1.1. Motivation and Problem Statement

In the past decade, digitalization has developed at a high-speed velocity, impacting almost every aspect of human life. In addition, recent black swan events, such as the COVID-19 pandemic, have underlined the indispensability of digitalization in business. Adapting quickly and being able to interact virtually and remotely have become essential, especially in the context of supply chain processes. As a consequence, there are various digital innovations to enhance supply chain performance. Several examples of them are Augmented Reality, Big Data, Cloud Computing, the Internet of Things, Nanotechnology, Omnichannel, Robotics, Sensor Technology, Self-Driving Vehicles, Unmanned Aerial Vehicles, and 3D Printing. These technologies make the supply chain faster, more transparent, more flexible, and globally connected (Büyüközkan & Göçer, 2018).

However, these technologies can influence supply chain sustainability. In this case, sustainability means the principle of ensuring that the actions today do not limit the range of economic, social, and environmental options open to future generations (Elkington, 1997). Influences can be positive or negative. One example regarding influence on the social side is 3D printing technology, which is beneficial for aging society in developed countries, while it can increase unemployment in developing countries (Gebler et al., 2014). Other example related to environmental side is implementation of automated warehouse operations which decreases electricity demand since most of lights in storage area are turned off, but usage of automated storage and retrieval systems increase electricity consumption due to increasing use of electronic machines and control systems (Nantee & Sureeyatanapas, 2021). In case of economic side, implementation of blockchain technology reduces communication cost in food supply chain (Kittipanya-ngam & Tan, 2020), while on the other research, it will be a challenge for small firms due to large initial investment and extra costs for the implementation (Nantee & Sureeyatanapas, 2021).

Those three aforementioned examples in each aspect of sustainability present contradictory situations of digitalization influence on supply chain sustainability. Therefore, this study research wants to scrutinize and shed light on the digitalization and sustainability relationship in the supply chain, while also seeking way on how digitalization can support sustainability.

1.2. Research Objectives and Research Questions

The gaps which are identified in the literature can be summarized below.

1. The lack of explanation on how digitalization influences supply chain sustainability positively and negatively
2. The connection of external and internal contingencies to the relationship between digitalization and sustainability in the supply chain

For those reasons, the objective of this research is to investigate and clarify the relationship between digitalization and sustainability in the supply chain and identify the external and internal contingencies which influence the relationship. Moreover, examples and counterexamples in the literature are also discussed to propose a theoretical framework that shows conditions in which digitalization can support supply chain sustainability.

These objectives are formulated into these research questions:

1. How can digitalization influence sustainability of supply chain?
2. What are the factors that can influence the relationship between digitalization and sustainability?

1.3. Research Methodology

To answer the research questions, the research methodology is explained as follows. Since study on the relationship between digitalization and sustainability is an overlooked area until now, the research objective is mainly exploratory. The research contains two sequential works. The first step is systematic literature review on peer-reviewed journals which the details will be explained in the next chapter. A theoretical framework will be constructed from the literature review. The second step is case studies on companies to confirm and clarify the framework. The type of research is qualitative since no statistical and mathematical work is involved. The research objective is to qualitatively analyze the relationship between digitalization and sustainability while examining the external and internal contingencies around the relationship.

1.4. Structure of The Work

The structure of the dissertation is presented below.

In Chapter 2, the Literature Review introduces Digitalization and Sustainability, then it is followed with Systematic Literature Review on relationship between digitalization and sustainability in the supply chain, and its external and internal contingencies that can influence the relationship. After that, Chapter 3 explains about

Research Design which is divided to four sections, starting with Case Study Methodology, Case Selection, Data Collection, and Data Analysis. In Chapter 4, Case Studies examines four company cases through With-In and Cross-Case Analysis. Next, Chapter 5 discusses about findings in the case studies, corroborates them with the theoretical framework from systematic literature review, and clarifies the relationship between digitalization and sustainability in the supply chain, especially on how digitalization can support supply chain sustainability. Then, Chapter 6 concludes and summarizes findings and discussions on the previous chapter while also suggesting directions for future research. Lastly, all references used in this dissertation are listed in Bibliography.

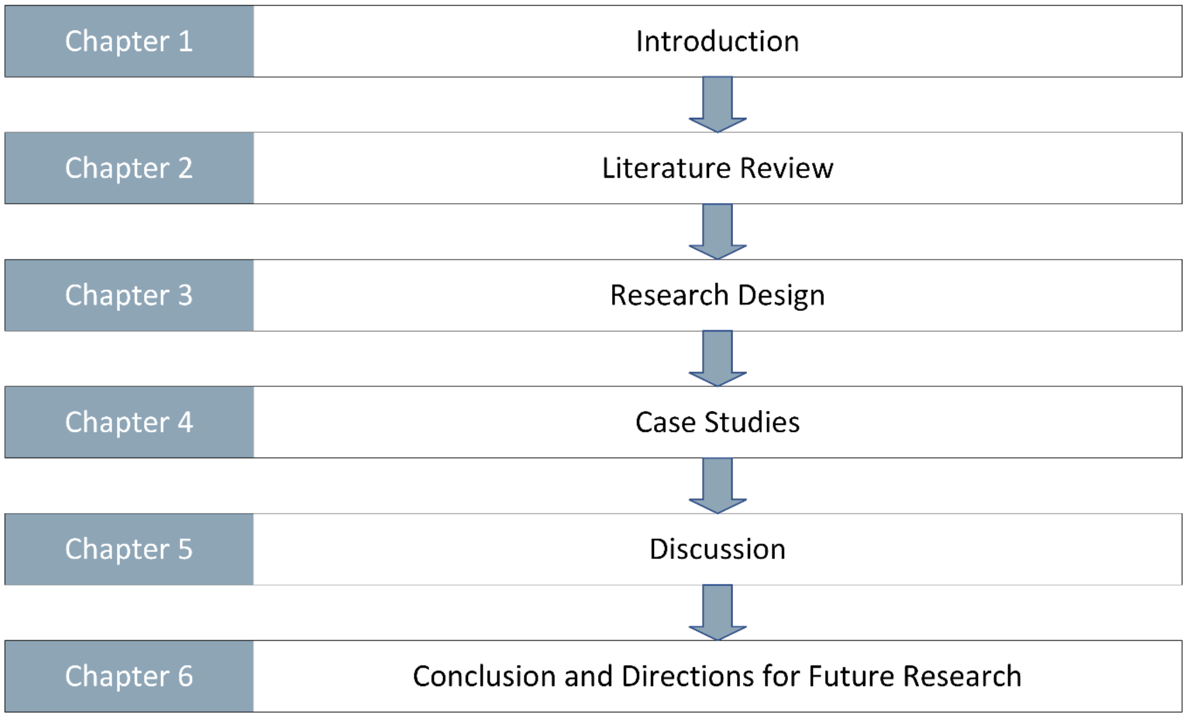

Figure 1.1: Dissertation Structure

2 Literature Review

2.1. General Introduction of Digitalization

Digitalization is the adoption or increase in use of digital or computer technology by an organization, industry, country, etc (OED Online, 2023a). In the context of work and employment, there are three ways of digitalization to deliver its impacts (Konle-Seidl & Danesi, 2022).

1. Work automation, which means replacing human with machine in the workplace.
2. Process digitization, which means converting physical information to digital format using artificial intelligence (AI), cloud computing and Big Data.
3. Coordination by platforms which refers to work coordination by means of platform.

2.1.1. Selected Factors to be Considered for a Successful Digitalization

Although digitalization harnesses technology in its operations, there are many aspects that should be considered to make digitalization and its implementation executed successfully.

2.1.1.1. Management

Top management holds a very important role in implementing digitalization. Management commitment plays a crucial role in establishing strategic framework of digital transformation and defining IT departments' expectation (Ko et al., 2022) which include business and IT strategy alignment to allow fast adaptation to dynamic situation (Aghimien et al., 2020; Cichosz et al., 2020). In addition to have management commitment, it is essential to obtain employees' commitment by setting and implementing digital transformation vision and objectives (Cichosz et al., 2020; Tanner & Richter, 2018).

After setting vision and goals, the implementation needs to be broken down into project and stages with agile project management approach by forming small cross-functional teams to align needs between team members (Cichosz et al., 2020). Moreover, the implementation should apply change management by taking human factor into account (Tanner & Richter, 2018). It is also essential to do simplification and standardization to the process before the digitalization to reduce errors, leading to higher service quality (Cichosz et al., 2020).

2.1.1.2. Design

Prior to executing the digitalization, it is necessary to focus on its design phase. Most mistake that company makes is adopting digital solution that fails to deliver a lasting impact due to insufficient rethinking when users lack the required mindset or skillset or when the solution loses relevance over time (Zoltners et al., 2021). To prevent premature digitalization decisions and ensure technology suitability to the organization, preassessment on digitalization readiness is crucial to be conducted (Ghobakhloo & Iranmanesh, 2021; Masood & Egger, 2019). In addition, it is recommended to gather suggestions and best practices from business partners in a similar industry while also visits their sites (Tanner & Richter, 2018). Participation from users that work in daily process and will use the digital solution is also essential to help the prioritization and design of system features, thereby encouraging the adoption (Tanner & Richter, 2018; Zoltners et al., 2021). Lastly, standardized internal process supported by accurate data is essential in the design phase (Tanner & Richter, 2018).

2.1.1.3. User

User of the digital solution is the one of the aspects in digitalization implementation. Their skill must be assessed (Tanner & Richter, 2018) and prepared by training and continuous support to encourage adoption in order to be familiar with the new technology and ensure effective and efficient utilization of the system (Masood & Egger, 2019; Zoltners et al., 2021). On the other side, people's resistance to change needs to be noted and managed with a well-structured change management process (Cichosz et al., 2020). Therefore, the training should be structured and continuous (Aghimien et al., 2020) to increase the digital maturity of the employees (Warner & Wäger, 2019) while also motivate them to give new ideas, foster growth mindset (Cichosz et al., 2020). These preparation efforts prevent users to perceive the solutions as liability and felt lack of control (Zoltners et al., 2021) and see the digital solution as a "friend" which does not replace their roles, but transforms their job (Schmitz et al., 2019).

2.1.1.4. Business Partners

In running a business, business partners are an integral part of a company's operations. In terms of digitalization implementation, company needs to carefully select their digital partner and consider collaborating with organization from other industries that have successfully integrated digital technologies into their services (Aghimien et al., 2020) and possess digital expertise (Tanner & Richter, 2018). Therefore, preassessment of technology maturity of business partners needs to be conducted (Tanner & Richter, 2018) to develop successful change management competency, digital expertise and strategic blueprint (Ghobakhloo & Iranmanesh, 2021).

2.1.2. Technologies of Digitalization

In terms of supply chain, several technologies which are already used in the industry to digitalize the system, can be found as below:

2.1.2.1. Blockchain

According to Treiblmaier (2018), blockchain is defined as a ledger which is digital, decentralized, and distributed in which transaction are logged in and chronologically added in its system with the goal to build records which are permanent and tamper-proof. Decentralized means a condition where the process of transaction is not controlled by a single entity. Meanwhile, distributed means a condition where computational tasks are split among several computers. Blockchain can be identified as an application which operates with internet access and facilitates economic transaction between system's participants. The system can serve as a system for registration and inventory to record, trace, monitor and conduct transactions of asssets which can be tangible, intangible, or digital (Wang et al., 2019).

2.1.2.2. Artificial Intelligence and Machine Learning

Generally, artificial intelligence can be defined as manifestation of intelligence by machines or computers which make them perform tasks that required human intelligence (Mason, 2003). Meanwhile, according to El Bouchefry & de Souza (2020), machine learning is a branch of artificial intelligence that involves developing dynamic algorithms to do data-driven decision making, contrasted with static programming models. In addition, machine learning enables computer programs to autonomously enhance their task performance through its experience.

2.1.2.3. Big Data Analytics

Big data analytics refers to a process of analyzing large and complex data to manage and plan present and future business operations (Jabir & Falih, 2022). Lany (2001) presented a concept of big data which are volume, velocity, and variety. In newer concept, big data has new V which is veracity (Hu et al., 2014; L'Heureux et al., 2017). Based on mentioned literature and Oliveira & Bollen (2023), these 4 Vs of big data can be explained as follows.

1. Volume, indicates the amount, size, and scale of data which reaches a point where it needs a specialized analysis tool to manage it.
2. Velocity, indicates the speed of data generation and its processing rate.
3. Variety, indicates the data heterogeneity which can originate from different sources and differ in type, semantics, volume, and format.
4. Veracity, indicates the data quality which is about bias, abnormality, and noise in data. The veracity of the data significantly influences the accuracy of data analytics processes.

2.1.2.4. Internet of Things (IoT)

Kiran (2019) highlights that Internet of things (IoT) means linking devices with power switches to the internet, so machines can communicate with other machines or through their built-in sensors which create an interconnected system. This interconnected system is practical for smart supply chain, smart manufacturing, smart infrastructure, and other related operations which need machine to machine communication. Several basic applications to illustrate the concept can be shown as follows:

1. Smart smoke detectors do not only act as alarm, but also sends alert to nearest fire station in case of fire, even if the owner is not at home.
2. Smart lighting systems can automatically turn on lights by movement sensors when someone enters the room.
3. Smart burglar alarm can send an alert to nearest police station when there is an unauthorized entry.

2.1.2.5. Cyber-Physical Systems

Monostori (2018) highlights that cyber-physical systems (CPS) are systems of interconnected computational entities which intensively interact with the physical surroundings and the on-going processes, simultaneously offer, and use data-accessing and data-processing services on the internet. Lee & Seshia (2017) stress that key importance of CPS is the interaction between the physical entities and its computational components.

2.1.2.6. Digital Twin

According to Grieves & Vickers (2016), idea of digital twin is digital information of physical system can be generated as an entity on its own, acts a physical system virtual counterpart, and integrated within the physical system itself.

2.1.2.7. Additive Manufacturing

ASTM International (2012) defines additive manufacturing as "a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies." One of mostly known additive manufacturing techniques is 3D printing which refers to object fabrication with deposition of a material using a nozzle, print head, or other printer technology based on ASTM International (2012) definition.

2.1.2.8. Augmented and Virtual Reality

According to Furht (2006), augmented reality is defined a system that overlays computer-generated information on real world environment to enhance its experience. Meanwhile, virtual reality is a technology that offers near realistic and convincing experiences in a synthetic or virtual environment.

2.1.2.9. Logistics 4.0

To expedite the business process in the supply chain, companies use technologies in their logistics systems. Nantee & Sureeyatanapas (2021) mentioned several technologies which are currently used for logistics 4.0.

1. Warehouse management system
2. Radio frequency identification (RFID) tags and auto-ID technology, to track material flows in real-time
3. Autonomous and self-controlled material handling and storage to load and unloading items, such as:
    a. laser-guided vehicle (LGV)
    b. automated guided vehicles (AGV)
    c. automated storage and retrieval systems (AS/RS)
    d. voice-directed warehousing (VDW)
    e. robot for picking, loading and unloading
    f. sortation conveyor system
4. Autonomous release of replenishment orders
5. Intelligent transportation system (ITS) to monitor and plan product distribution in real-time
6. Telematics control unit (TCU) to track freight locations and retrieve relevant data to optimize the drivers' routes.

2.1.2.10. E-Commerce

Electronic commerce or e-commerce is the exchange of products or services using electronic networks, such as internet and computer networks (Shen et al., 2012). Goldfarb (2008) underlined that e-commerce does not only comprise companies that utilize internet to reach other businesses or customers directly, but also businesses that act as intermediaries. In addition, the definition is not limited to only online businesses, but includes businesses that operate both online and offline, and businesses that use internet, but not as their main business area.

2.1.2.11. Internet of People

Conti & Passarella (2018) argued that internet of people is a radical and new human-centric approach to internet's data and its knowledge. It is a system where personal devices can communicate, exchange, and manage data on behalf of their users (Conti et al., 2017).

2.1.2.12. Cloud Manufacturing

Ghomi et al. (2019) underline cloud manufacturing as a new manufacturing model which runs on computer networks with a goal of using virtual distributed resources, including manufacturing hardware, software, and capabilities, while the service is delivered by manufacturing resources. To deliver the capability, several technologies should be available, such as cloud computing, IoT, RFID, and service oriented.

2.2. General Introduction of Sustainability

Sustainability comes from word “sustainable” which means capable of being maintained or continued at a certain rate or level (OED Online, 2023b). However, the meaning of sustainability has shifted in recent decades. Sustainability is meeting the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). John Elkington, a British business author who coined “Triple Bottom Line” and “People, Planet, Profit” terms in his book of “Cannibals with forks”, highlights the pillars of sustainability which are economic, environmental, and social.

2.2.1. Economic Sustainability

Economic sustainability refers to a process of production which satisfies present level of consumption without compromising future needs (M. A. Khan, 1995). In addition, economic sustainability is not only about gaining economic growth year after year, but also recognizes that the economic growth is considered sustainable if it enhances both quality of life and environment (Jeronen, 2013).

2.2.2. Environmental Sustainability

Goodland (1995) brings a concept of environmental sustainability which means enhancing human welfare by preserving raw material sources for human needs while make sure that sinks for human wastes are not surpassed their limit, in order not to harm humans. Therefore, environmental sustainability is the adoption of sustainable development by governments, corporations, and other organizations in response to concerns about climate change and natural resources consumption, which are encouraged by consumers and activists who give pressures to large corporations to implement environmentally friendly practices (Jeronen, 2013).

2.2.3. Social Sustainability

Jeronen (2013) emphasizes social sustainability as the way companies evenly distribute welfare between those who contribute within the organization and the supply chain. The goals of the contributions are improving well-being and quality of life of individuals and society in current and future generations. For instance, companies can improve employees’ cognitive ability by providing training, and enhance working conditions by supplying health and safety equipment if needed and regulating room temperature to make comfortable working environment.

2.3. Systematic Literature Review on Relationship between Digitalization and Sustainability in the Supply Chain

2.3.1. Review Methodology

Systematic literature review is a literature review method which is both explicit and reproducible (Booth et al., 2016). It contains literature searching, quality assessment, synthesis of literature, analysis of review findings, and findings presentation. Those steps are important to ensure future studies can reproduce and develop the study (Jafari Navimipour & Charband, 2016). This study conducts systematic literature review as follows. The literature review uses two main databases of journals which are Scopus[1] and Web of Science[2]. To search the literature, several strings are used to seek the keywords in title, abstract, and keywords of the abstract which can be seen in Table 2.1. The acquisition date of each keyword is also provided.

Table 2.1: Keywords and their acquisition dates.

No.	Keywords	Acquisition Date
1.	("digital" OR "digitalization") AND "supply chain" AND ("sustainable" OR "sustainability")	17 March 2023
2.	("digital" OR "digitalization") AND "supply chain" AND ("social" AND ("sustainable" OR "sustainability"))	19 March 2023
3.	("digital" OR "digitalization") AND "supply chain" AND (("environment" OR "environmental") AND ("sustainable" OR "sustainability"))	19 March 2023
4.	("digital" OR "digitalization") AND "supply chain" AND (("economy" OR "economic") AND ("sustainable" OR "sustainability"))	19 March 2023
5.	"smart" AND "supply chain" AND ("sustainable" OR "sustainability")	19 March 2023
6.	"smart" AND "supply chain" AND ("social" AND ("sustainable" OR "sustainability"))	19 March 2023
7.	"smart" AND "supply chain" AND (("environment" OR "environmental") AND ("sustainable" OR "sustainability"))	19 March 2023
8.	"smart" AND "supply chain" AND (("economy" OR "economic") AND ("sustainable" OR "sustainability"))	19 March 2023

[1] https://www.scopus.com/search/form.uri?display=basic#basic
[2] https://www.webofscience.com/wos/woscc/basic-search

Regarding the inclusion criterions, literature which are considered for the review are only articles and reviews of journals in English. The subject areas of literature which are considered are shown in Figure 2.1 and Figure 2.2 below.

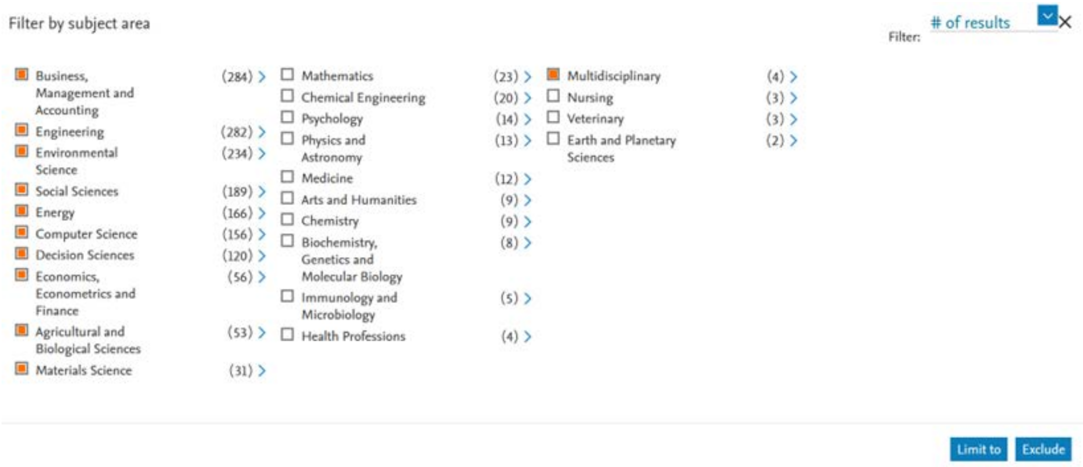

Figure 2.1: Considered subject areas of literature in Scopus.

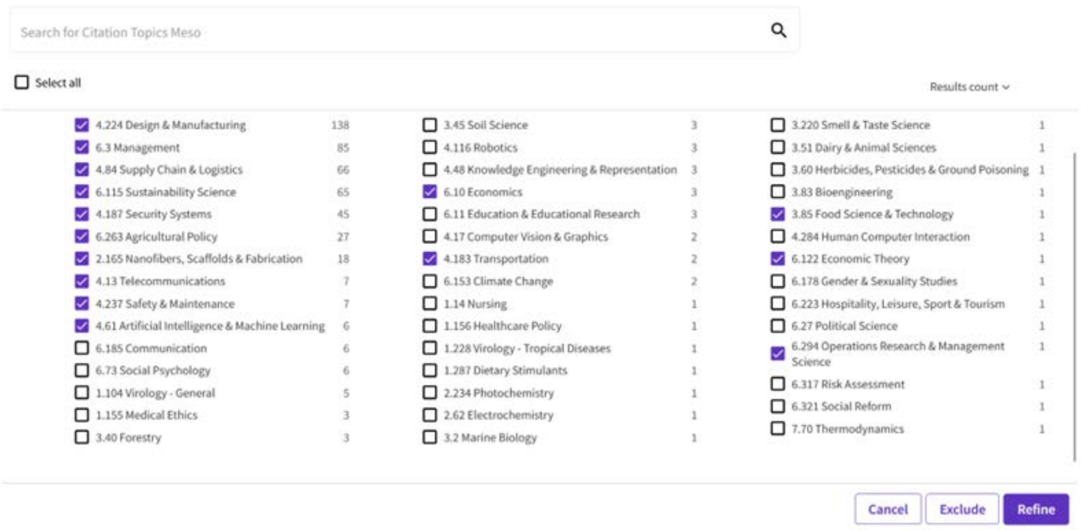

Figure 2.2: Considered subject areas of literature in Web of Science.

After applying all mentioned criteria and gathering all literature from the sources, duplicates of literature are removed. Next, the quality of remaining papers is checked. To check the quality of the journals, SCImago Journal & Country Rank[3] is used and only papers with 1st quartile journal quality are accepted. The next step is reading the title and abstract of the papers to filter qualitatively the literature which is related to the research theme. After that, the remaining papers are read carefully to conclude the final shortlisted papers. Table 2.2 contains information regarding the number of papers associated with each process.

[3] https://www.scimagojr.com/

Table 2.2: Sample selection.

Process description	No. of remaining articles
Search string: all keywords mentioned above applied on Scopus (S) and Web of Science (W)	3,909 (S); 2,797 (W)
Inclusion criteria: Articles, Reviews; English	2,239 (S); 2,460 (W)
Subject area: as listed on previous pictures	2,194 (S); 1,840 (W)
Remove duplicates	1,164
Quality check: only Q1 in SCImago	537
Title & Abstract check: read qualitatively	158
Final shortlisted: read thoroughly	72

The shortlisted papers are read thoroughly to find supporting sentences related to four pillars to build a theoretical framework. Those pillars are positive and negative impacts of digitalization on sustainability, and external and internal factors which can influence both impacts. After sentences for pillars are gathered, sentences that have the same gist are clustered into words that represent the gist. Finally, a theoretical framework is constructed based on those four pillars with its clusters.

2.3.2. Descriptive Analysis

2.3.2.1. Publication Year

The final shortlisted papers contain 72 papers. Figure 2.3 shows the distribution of the papers across years of publication. It highlights a steep increase of publication trend from 2020 until 2023 (up until 19 March 2023) with 90% of reviewed studies published during these years. This upward trend confirms the importance of investigating digitalization and its influence on sustainability in the supply chain, especially for the past three years.

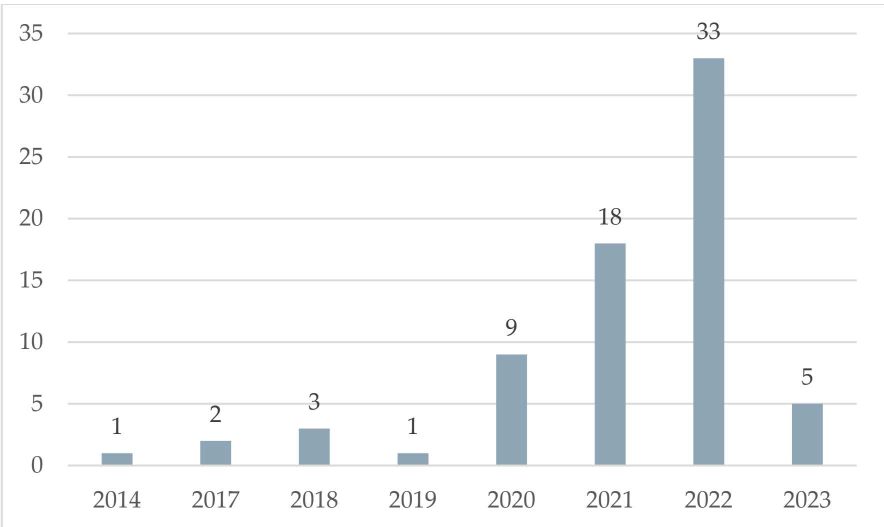

Figure 2.3: Distribution of literature across years of publication.

2.3.2.2. Publication Journal

The credibility of journal impacts on how public perceives the publication. Table 2.3 shows that *Journal of Cleaner Production* (n=13), *Operations Management Research* (n=6) and *International Journal of Production Research* (n=5) are top three 1st quartile journals to publish influence of digitalization on sustainability in the supply chain, especially in this literature review.

Table 2.3: Distribution of papers among journals.

Name of Journal	No. of papers
Journal of Cleaner Production	13
Operations Management Research	6
International Journal of Production Research	5
Annals of Operations Research	4
Business Strategy and the Environment	4
Production Planning & Control	4
Sustainable Production and Consumption	4
International Journal of Logistics Research and Applications	3
Management of Environmental Quality: An International Journal	3
Resources, Conservation & Recycling	3
Technological Forecasting & Social Change	3
Benchmarking: An International Journal	2
International Journal of Production Economics	2
Process Safety and Environmental Protection	2
Others (1 paper per journal)	14

2.3.2.3. Publication Topic

Figure 2.4 shows topics that are mainly discussed in the papers under review. It should be noted that one paper can explore more than one topic. Contingencies or factors that can influence the relationship between digitalization and sustainability is the most examined topic. Meanwhile, *blockchain* (n=24), *internet of things* (n=11) and *big data analytics* (n=10) are the top three technologies in supply chain which are currently discussed in recent years. Topics which are only mentioned once in papers under review are included in *others* (n=8), i.e., smart wearables, e-commerce, procurement 4.0., Industry 5.0, digital twin, digital supply chain network, business intelligence, and 3-dimensional virtual and digital.

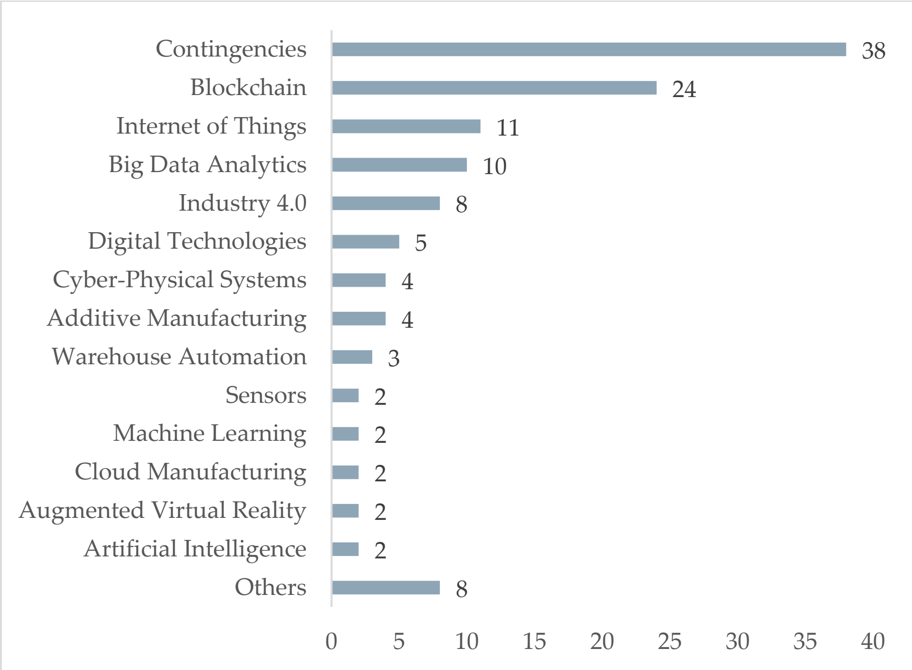

Figure 2.4: Distribution of topics in reviewed papers.

2.3.2.4. Publication's Type of Research

Table 2.4 shows the summary of methodologies which are harnessed by the selected 72 papers. The top three employed methodologies in current systematic literature review are literature review, especially systematic literature review (n=14), followed by survey (n=13), and mixed methods (n=12). Mixed methods combine quantitative and qualitative research methods.

Table 2.4: Methodologies used by reviewed papers.

Research Method	# of papers	Annex
Literature Review	16	Systematic Literature Review/SLR (n=14) Literature Review (n=2)
Survey	13	
Mixed Methods	12	BWM & Case Study Conceptual & ISM Delphi & ISM-ANP Fuzzy DEMATEL & Interviews Item-Objective Congruence & Q-sort Literature Review & Content Analysis Fuzzy BWM & Delphi Fuzzy Delphi, Fuzzy DEMATEL, ANP Scientometric Analysis & Critical Review SLR & AHP SLR & Content Analysis SWOT, STRATH, FuDE-VIR, DEMATEL, Delphi

Multiple Criteria Decision Making	9	AHP AHP-DEMATEL COPRAS-SWARA Fuzzy AHP–TODIM Fuzzy Cognitive Map Grey-DEMATEL ISM Neutrosophic-AHP SWARA-TODIM
Mathematical / Modelling	6	Partial Least Squares Structural Equation Modelling Panel Smooth Transition Regression
Case Study	5	
Conceptual	4	
Delphi	3	
Others	4	In-depth Interview Critical Taxonomy Scoping Studies Desk Research

2.3.2.5. Publication's Context of Industry

Figure 2.5 shows context of industry which the paper researched in. *Manufacturing* (n=15), *agriculture* (n=8), and *logistics* (n=5) are the main industries where most research about relationship between digitalization and sustainability in supply chain took place, particularly in this literature review.

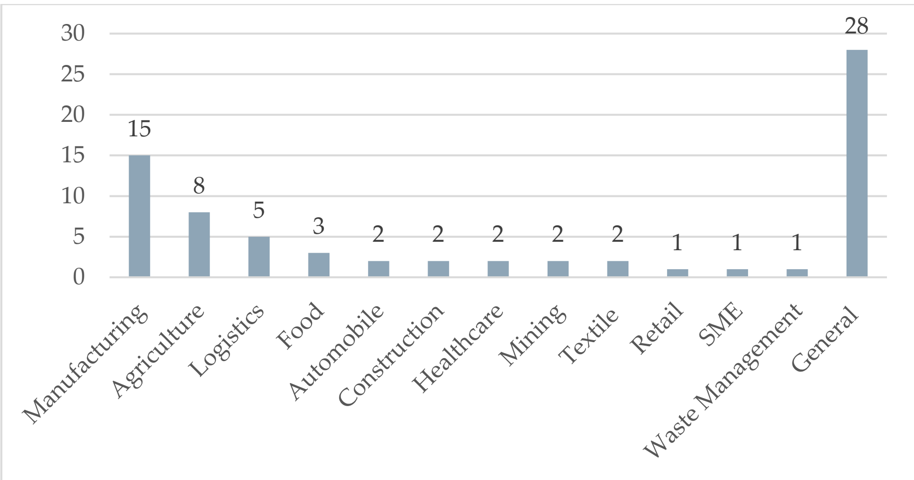

Figure 2.5: Distribution of papers' context of industry.

2.3.2.6. Geographical Context of Publication

Figure 2.6 shows countries where the research of the papers took place. It should be noted that one paper can conduct research in several countries. Asia, especially

China and India, is the continent where most research with geographical focus took place.

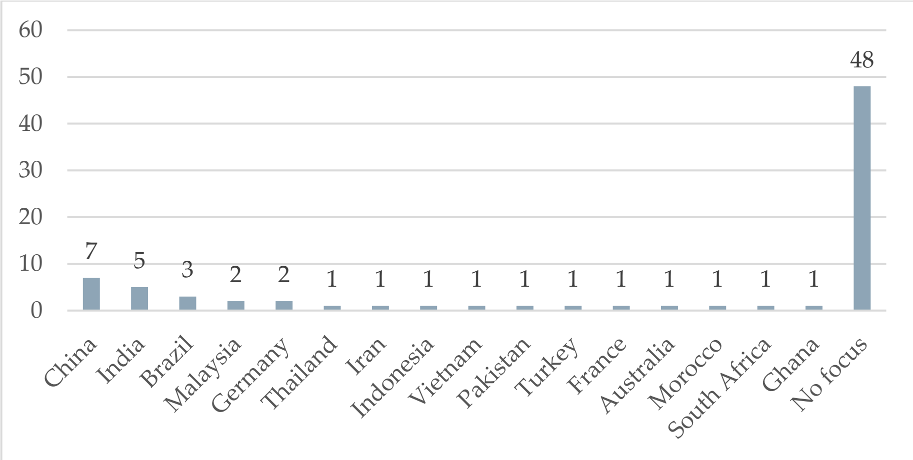

Figure 2.6: Distribution of papers' geographical context.

2.3.3. Positive Impact of Digitalization on Sustainability

Positive impacts refer to results or effects which are happened due to activities and/or implementation of digitalization in the supply chain processes and positively influence all sustainability aspects (economic, environmental, and social). After reviewing the literature and grouping the facts qualitatively, it is found that there are ten positive impacts of digitalization on sustainability. Those are increasing process efficiency, enabling real-time operations and data-driven decision making, improving company's financial condition, increasing resource usage efficiency, reducing waste and emission, improving employment condition and development, enabling process transparency, enabling compliance monitoring, enabling community empowerment, and enabling better product and service provision to customers.

2.3.3.1. Increase Process Efficiency

Digitalization in the supply chain enhances process efficiency across types of industries, particularly in streamlining business process operations. Schilling & Seuring (2023) reported that implementation of digital technologies makes supply chain processes more flexible and responsive. It also allows businesses to do self-mapping to integrate their entire lifecycle to circular economy (Ghobakhloo et al., 2022; Yu, Khan, et al., 2022). Furthermore, these technologies offer hyperconnectivity that maximize companies' productivity and competitiveness while usher and influence companies to more sustainable practices and operations (Ghobakhloo et al., 2021; M. Sharma et al., 2022).

Blockchain is one of digital technology which improves supply chain efficiency by enhancing prediction in machine maintenance and decreasing rework and recall product defects, leading to attain circular economy. Esmaeilian et al. (2020) found that blockchain improves efficiency in systems and operations. Meanwhile, Chaouni Benabdellah et al. (2023) identified blockchain enables supply chain integration by reducing supply chain inefficiencies and disruption. Examples of blockchain implementation in automobile sector are evaluating machine condition, predicting parts to be replaced and optimizing parts to extend their lifetime (Yu, Umar, et al., 2022). Blockchain also helps in tracking substandard product and trace its further transactions, so then effort to rework and recall can be reduced (Saberi et al., 2019). In healthcare sector, blockchain improves supply chain performance to achieve circular economy (Vishwakarma et al., 2022).

Other versatile technology which is implemented in supply chain is machine learning (ML) and AI. In agricultural sector, ML applications in irrigation systems can enhance crop yield and productivity (R. Sharma et al., 2020). Furthermore, AI technologies allow the user at agricultural stage to test soil, increase crop yield, automatically distinguish ripe products, anticipate crop disease. Meanwhile, it also assists new plant-based product development (Hassoun et al., 2022). In addition, product distribution process is improved by using ML algorithms to predict shipment delays, optimize vehicle routing and improve fleet management (R. Sharma et al., 2020). Besides ML, big data analytics (BDA) is also harnessed to optimize truck route which enables more efficient logistics route, so total logistics cost can be decreased (Kunkel et al., 2022). Additionally, it enhances the product delivery times to end consumers (Dongfang et al., 2022).

Automation has been used in many industrial processes, including the supply chain process and have beneficial effect in developed countries with aging society (Gebler et al., 2014). For instance, implementation of automated storage and retrieval systems (AS/RS) in warehouse can potentially increase space utilization by up to 30% while also eliminate human error in arranging items, documents, and shipping which can make product damage and loss. The effects of this warehouse management system are decreasing customer complaints and increasing customer satisfaction (Nantee & Sureeyatanapas, 2021).

Harnessing Internet of Things (IoT) in supply chain enables performance improvement. In agri-food sector, IoT assists vegetable supply chain to control and monitor accurately numerous agricultural operations that increases crop productivity (Hassoun et al., 2022). In retail sector, IoT allows data sharing between suppliers and retail points which enhances the processes to meet retailers' inventory needs (de Vass et al., 2021).

The manufacturing sector is the one of industries that is mostly impacted by digitalization in its supply chain. For example, digital twins make manufacturing industry able to integrate various data, so its production system can change state during ongoing operations (Kamble et al., 2022). In particular, cyber-physical systems (CPS) and intelligent manufacturing execution systems (IMES) increases productivity (Ching et al., 2022). Specifically in apparel manufacturing industry, additive manufacturing (AM) assists to print prototypes instantly, detect design flaws immediately and allow faster iteration process (Hohn & Durach, 2021). Another technology named 3-dimensional virtual and digital (3DVD) simplifies apparel industry by introducing zero-waste design, enabling innovative pattern making, and allowing made-to-measure approach which can streamline process and reduce cost (Casciani et al., 2022).

Several cases in the industry use more than one digital technology to improve supply chain performance. For instance, implementation in managing food waste in Brazil harnessed Big Data, AI and machine learning (ML) to detect fruits and vegetables (F&V) deterioration and using robots to reduce handling of those items by employees, so the product qualities are maintained (de Souza et al., 2021). In Indonesia, cyber-physical system (CPS), IoT, Big Data and other Industry 4.0-related technologies facilitate real-time data changes and keep important information regarding coffee goods life cycle in coffee industry to effectively respond to operational uncertainty (Tseng et al., 2022)

2.3.3.2. Enable Real-Time Operations and Data-driven Decision-Making

Digitized manufacturing system enables real-time capability of manufacturers (Ghobakhloo, 2020). Furthermore, digital transformation gives effect on sustainable supply chain firm performance since it enables real-time information management and demand-based production, reduces uncertainty risk with predictive learning and maximize usage of resource by maximum information utilization (Nayal et al., 2022). For instance, in pharma supply chain, Industry 4.0 enables real-time coordination and communication efficiency (Ding, 2018).

AI, BDA, and blockchain are several technologies that enable real-time and data-driven decision making. AI assists to provide more robust and quantitative solutions to multi-criteria decision making, especially in an imprecise environment (Wilson et al., 2022). BDA assists cost and performance continuous monitoring with appropriate metrics (Kazancoglu et al., 2021). Specifically in food companies, BDA helps to do optimal decision-making by extracting hidden and invaluable information (Zhong et al., 2017). Meanwhile, blockchain offers numbers of competitive, one of them is enabling real-time tracking of transactions (Sahu et al., 2023).

2.3.3.3. Improve Company's Financial Condition

Digitalization helps companies in improving their financial condition by reducing operational cost, increasing savings due to elimination of non-added value activities, and increasing profit through more seamless business processes. Businesses using Industry 5.0 technology have improvement in economic growth (Ghobakhloo et al., 2022). For instance, blockchain helps to lower manufacturing costs (Sahu et al., 2023) and enables balance between economic and environmental condition by considering operational cost and emissions cost (Manupati et al., 2020). In addition to blockchain, digitized manufacturing system and digital supply chain network assist manufacturer to decrease production cost (Ghobakhloo, 2020; M. Sharma et al., 2022). As evidence, in Morocco, adopting digital technologies in manufacturing companies, such as enterprise resource planning and IoT enhances supply chain integration which impacts economic performance positively (Oubrahim et al., 2023). Similarly, usage of automated transfer and distribution equipment in manufacturing industries has low operational cost and high efficiency (Bechtsis et al., 2017). In specific case of apparel industry, apparel design process is simplified by using 3DVD, so the costs can be reduced (Casciani et al., 2022). Likewise, 3D printer saves two thirds of production cost due to shorter supply chains, decreased material demands and reduced handling. Additionally, one thirds of the cost is saved from reduced fuel usage (Gebler et al., 2014).

There are several cases in industry that highlight how digital technologies help enhance company's financial condition. In procurement, digitalization accumulates savings, enhances profit and supply chain transparency which drives down maintenance costs (Bag et al., 2020). In warehouse management, AS/RS implementation is potentially driving down firm's costs by around 50%, specifically workers' needs, such as salary and its taxed, insurance, taxes, and training costs (Nantee & Sureeyatanapas, 2021). In mineral supply chain, blockchain decreases the supply chain and transaction cost (Yousefi & Mohamadpour Tosarkani, 2022). In agricultural sector, Mukherjee et al. (2022) finds that blockchain helps to decrease cost, while R. Sharma et al. (2020) highlight usage of remote sensing systems and ML algorithms drive down operating cost. In food supply chain, Kittipanya-ngam & Tan (2020) underline that, e-commerce can reduce intermediaries which impacts to a profit margin increase, while the usage of blockchain along with IoT provides transparency and traceability which can reduce communication cost. In retail firms' supply chain management (SCM), IoT implementation can decrease cost, boost growth, and bring positive return on investment (de Vass et al., 2021). In addition, to overcome F&V waste in supermarket supply chain, big data, AI, and ML can do dynamic pricing based on F&V deterioration stage which yield to sales increment, and accurately forecasting sales which decreases farmers' costs and increases supermarket's profits (de Souza et al., 2021).

2.3.3.4. Increase Resource Usage Efficiency

Implementation of Industry 4.0 on sustainable development results in enhancement of resource efficiency (Khan et al., 2021) and potentially drive down energy consumption by applying intelligent devices and smart production systems (Ghobakhloo et al., 2022; Kamble et al., 2018). In addition, adoption of digital technologies can benefit companies economically while also improve their sustainability outcomes, such as decreased raw material and water consumption as well as better energy efficiency (Oubrahim et al., 2023). In the context of data management, digital technologies play a crucial role in the management of unstructured data to provide effective decision-making, precise forecasting, and active consumer involvement in feedback, thereby increasing green practice performance and sustainability objectives which one of them is resource efficiency (Nayal et al., 2022).

Industry 4.0 consists of several technologies, each of them has its own advantage in term of resource usage efficiency. For instance, blockchain aids reducing resource consumption by enabling substandard products tracking until their further transaction, so rework and recall activities can be reduced (Saberi et al., 2019). In addition, 3D printing uses lower input resources as it can print goods without excess losses (Gebler et al., 2014). Similarly, RFID tags and IoT are used to ensure environmental compliance while also optimize resource usage (Lopes de Sousa Jabbour et al., 2018). Another example, digital twin improves resource utilization by saving energy obtained from analyzing energy consumption and optimizing the consumption schedules (Kamble et al., 2022). Meanwhile, adoption of AS/RS has significantly reduced liquified petroleum gas (LPG) due to reduced dependence on combustion-powered forklifts (Nantee & Sureeyatanapas, 2021).

There are several implementations in different kind of supply chain that show how digital technologies boost resource usage efficiency. In manufacturing industry, Industrial IoT implementation (IIoT, CPS and big data analytics) enables real-time and continuous monitoring of production processes which results in resource efficiency and energy consumption reduction (Ching et al., 2022; Ghobakhloo et al., 2021; Kunkel et al., 2022) throughout manufacturing clusters and distribution channels (Ghobakhloo, 2020). In agriculture supply chain, machine learning applications helps to efficiently manage resources (Sharma et al., 2020). In mineral supply chain, blockchain can decrease irresponsibly produced minerals (Yousefi & Mohamadpour Tosarkani, 2022). In electrical and electronic equipment supply chain, digitalization enables servitization business model to collect electronics at the end of usage life which drives down waste and virgin resources extraction (Bressanelli et al., 2021). Additionally, conservation of scarce natural resources can be also optimized by procurement digitalization (Bag et al., 2020). In pharma industry, Industry 4.0 enables the industry to do continuous production which can decrease material utilization and bring contribution to environmental protection (Ding, 2018). In port logistics, digitalization assists urban planners, policymakers, and port administrators to effectively manage the movements of resources and raw materials (D'Amico et al., 2021).

2.3.3.5. Reduce Waste and Emission

Industry 4.0's advantages, such as improvement in cost reduction, manufacturing efficiency and profitability are anticipated to support optimization of energy and resource throughout value networks, resulting in decreased complexity of waste and emissions reduction, while also achieving better energy and resource efficiency (Ghobakhloo, 2020; Ghobakhloo et al., 2021, 2022; Kamble et al., 2018). As an example, Oubrahim et al. (2023) stress that by leveraging digital technologies, Moroccan companies can effectively minimize its waste and emissions generated from its manufacturing operations. In the context of unstructured data management, digital technologies enable accurate forecasting, improved decision-making and better consumer engagement in feedback which enhances green practices performance and sustainable goals, especially emission and waste reduction (Nayal et al., 2022). In relation to procurement, digitalization has potential to substantially minimize waste in the supply chain by eliminating warehouse issues which are overstocking and understocking inventory (Bag et al., 2020). Another case by Ding (2018) finds that Industry 4.0 implementation in pharma industry allows continuous production which decreases greenhouse gas emission, resulting in significant contributions to environmental protection. In the port logistics, digitalization enables policymakers, urban planners, and port administrators to effectively control various resources movement, including waste and emissions, minimize the waste of unused resources (D'Amico et al., 2021).

Blockchain is one of the technologies that can realize previously mentioned improvements. Blockchain enables supply chain sustainability by tracking substandard products and its further transactions which help to decrease greenhouse gas emissions and carbon footprint (Saberi et al., 2019; Yu, Umar, et al., 2022). In Northern Europe, blockchain increases people's motivation of recycling with financial incentives in the form of cryptocurrency token for depositing recyclable items such as bottlers, plastic containers, or cans (Saberi et al., 2019). In healthcare sector, blockchain implementation helps its supply chain to manage the process, leading to waste reduction (Vishwakarma et al., 2022). In agri-food supply chain, blockchain integration with RFID and smart packaging technologies helps identifying location and expiration details of food products, leading to food waste reduction (Pakseresht et al., 2023).

In addition to blockchain, IoT, CPS and IMES can deliver the same positive impact. In agrifood supply chain, integration with IoT allows to reduce supply-demand imbalances and food surplus, resulting in food loss reduction (Pakseresht et al., 2023). Meanwhile, IoT implementation in retail firms' SCM enhances environmental sustainability which is evident mainly through decreased waste and carbon footprint, paperless operations, and recycling (de Vass et al., 2021). In addition, combining IoT implementation with CPS enables companies to gather data from processes and machines to detect potential failures that can lead to wastage (Lopes de Sousa Jabbour et al., 2018). Another example by Ching et al. (2022) highlight that manufacturing industries can curtail waste throughout various industrial operations through utilization of CPS and IMES.

Besides all mentioned technologies, there are also other technologies that help to lower waste and emission. For instance, implementation of Big Data, AI and ML enables Brazilian supermarkets to manage pricing, item display and storage of F&V, so near expired F&V can be sold, thereby reducing food waste (de Souza et al., 2021). In agricultural sector, application of machine learning aids to manage resource efficiently, leading to food losses reduction (R. Sharma et al., 2020). Meanwhile, 3D printing has capability to reduce CO2 emissions through shorter and more direct manufacturing method (Gebler et al., 2014).

2.3.3.6. Improve Employment Condition and Development

Industry 4.0 enhances working conditions with its technical assistance systems (Beltrami et al., 2021), strengthens organizational structures, skills, and employee well-being (I. S. Khan et al., 2021), while also ensures a safe workplace for employees and manages proactive inventory (M. Sharma et al., 2022). In addition, it also creates more employment opportunities in long term, raise worker salaries, enhance working conditions, and promote internationalization to address corporate inequality (Ghobakhloo et al., 2021).

Real-time communication facilitates enhancement in production reliability, safety of work environment, decision-making process, risk management and increased stakeholders' responsiveness (Ghobakhloo et al., 2022). One of technologies to deliver the task is IoT which enables communication between different functional silos within retail firms, allows key personnel to access data efficiently. In addition, it also enhances safety and job satisfaction, fosters community development, and opens new employment opportunities, which can translate into long-term value creation (de Vass et al., 2021). Additionally, the Internet of People and smart wearables provide a safer, better, and more enjoyable working environment for employees. In addition, Internet of People enhances customer engagement and eliminates communication gaps among employees (Ghobakhloo et al., 2021).

Digital technologies help to eliminate human errors and decrease delays and transaction time while enhancing employees' well-being, work environment, and job satisfaction (Oubrahim et al., 2023). As an example, intelligent automation assists to prevent industrial accident, increase workforce capabilities, and enhance workplace safety and job satisfaction (Ghobakhloo et al., 2022). Similarly, Nantee & Sureeyatanapas (2021) highlight use of AS/RS in warehouse reduces forklifts usage by around 80-90%, which significantly eliminate air pollution in the warehouse. Furthermore, it also decreases job-related accidents and occupational illnesses caused by forklifts and workers' ignorance of safety protocols. Besides, it eliminates manual lifting and loading which offers human ergonomic benefits. In addition, environmental-friendly automated guided vehicles (AGV) help manufacturers and practitioners to increase flexibility and eliminate failures while operating 24/7 in a labor intensive and accident-free workplace (Bechtsis et al., 2017). Moreover, implementation of these technologies creates opportunities for employees to propose improvement ideas and works, since their various tasks have already been handled by machines. Both systems also simplify employees' tasks, allow development of employees' analytical and computing skills, and gain new knowledge through job expansion and rotation, thereby allowing senior operators to enhance their analytics competence (Nantee & Sureeyatanapas, 2021). To streamline the employee development, it is required to provide job-transition opportunities to make employees embrace digitalization by encouraging them to update their skills with continuous education (Casciani et al., 2022). In addition, digital technologies, such as Augmented and Virtual Reality (AVR), smart apps, IIoT-enabled information sharing, and data analytics tools greatly enhance the efficiency of talent screening and acquisition, learning program, on-the-job training, and career development programs (Ghobakhloo, 2020).

Besides previously mentioned technologies, there are several technologies that can deliver improvement in employment conditions and development. One of them is AM which reduces subcontracting in apparel industry which benefits social sustainability as larger proportion will be conducted under monitored working conditions while also decreases supply chain complexity (Hohn & Durach, 2021). Other example is digital twins that allows to collect employees' information regarding their work schedules and tasks which can be utilized to assess their wages and working conditions, thereby providing social benefits (Kamble et al., 2022). In port logistics, real-time monitoring in logistics process enhances safety and convenience of drivers operating industrial vehicles, trucks, and ships through implementation of assisted or autonomous driving systems to prevent accidents and collisions. This implementation also assists urban planners, port administrators, and policy makers to ensure faster, safer, more practical, more flexible, and more informed decision-making processes (D'Amico et al., 2021).

2.3.3.7. Enable Process Transparency

Industry 5.0's function of data sharing and transparency increases visibility, traceability, and transparency which are crucial to supply chain resilience (Ghobakhloo et al., 2022). Blockchain is one of digital technologies that realizes that function. Blockchain technology transforms supply chain management by supporting its visibility and traceability (Manupati et al., 2020) and increased its transparency (Sahu et al., 2023). In the context of visibility, blockchain supports visibility of product lifecycle, sustainability reporting and monitoring (Esmaeilian et al., 2020). Meanwhile, transparency by blockchain can potentially eliminate intermediaries from transactions, thereby eradicates opportunistic behaviour (Chaudhuri et al., 2021). Other advantages of blockchain are ensuring stability and immutability of information, easing process of products' footprint tracing, supporting emission trading schemes efficacy, preventing fraud (Saberi et al., 2019), and avoiding unauthorized change by corrupt individuals or organizations, so then it can safeguard personal assets from unfair seizure (Chaudhuri et al., 2021). These advantages increase consumers' confidence related to sustainability concerns by granting access to comprehensive and verifiable information about products (Kshetri, 2021).

In several cases of supply chain, blockchain supports transparency and traceability of mineral supply chain (Yousefi & Mohamadpour Tosarkani, 2022) and agri-food product supply chain (Kamble et al., 2020), especially in monitoring food safety and trace product during incidents (Pakseresht et al., 2023). In construction supply chain, blockchain offers trust-enhanced information sharing by tamper-proof and traceable information sharing (Yoon & Pishdad-Bozorgi, 2022).

Besides blockchain, there are several digital technologies that enhance process transparency. IoT and other smart devices enable customers to trace the products' sources which is enhancing their experience (Sharma et al., 2020). Likewise, IoT along with blockchain have an essential role to verify supplies and upstream operations in relation to sustainability and traceability concerns (Kittipanya-ngam & Tan, 2020). Other technology like BDA assists manufacturing industries to eliminate complexity of flow and validation of information, thereby reducing information asymmetry (Edwin Cheng et al., 2022). In addition to previous technologies, decentralized database impacts sustainable practices, including transparency and immutability of data (Mukherjee et al., 2022).

2.3.3.8. Enable Compliance Monitoring

Blockchain technology can assist in ensuring regulatory compliance through tracking production and distribution processes (Kshetri, 2021). In cobalt supply chain, blockchain is used to verify its origin, specifically to identify if there is child labor presence (Bernards et al., 2022). In sourcing process, implementation of digital supply chain and procurement technologies (DSCP-technologies) allows companies to assess the environmental compliance and sustainability performance of contractors / suppliers (Yevu et al., 2021). For instance, storing information in blockchain-based, reliable and publicly accessible cloud infrastructure which is proposed by GAIA-X project, can provide independent assessment of environmental parameters throughout the supply chain through collaborative development of algorithms between supply chain partners (Kunkel et al., 2022).

Specifically in construction supply chain, blockchain-based data storage is harnessed to facilitate the storage and sharing of supplier data or construction materials data related to sustainability. As a result, stakeholders can select and evaluate suppliers based on their sustainable performance reputation and also verify sustainability performance of construction materials (Yoon & Pishdad-Bozorgi, 2022). Blockchain's features of immutability and transparency implementation in construction supply chain also have potential to facilitate the process of obtaining green certifications for construction products and services in construction supply chain and procurement (CSCP) (Yevu et al., 2021).

In carbon footprint calculation, blockchain technology simplifies process of tracking product footprint of a specific company while also aids in determination of carbon tax that should be charge to the company (Saberi et al., 2019). In addition, DSCN contributes to several outcomes including carbon emissions compliance with government regulations (M. Sharma et al., 2022).

Another technology, such as digital supply chain twin allows focal companies to consistently monitor and regulate sustainable actions of their suppliers (Kamble et al., 2022).

2.3.3.9. Enable Community Empowerment

Transparency caused by blockchain results in positive social outcomes in supply chains related to coffee and seafood which are enhancing the living standards and well-being of low-income individuals (Kshetri, 2021). Therefore, firms need to be encouraged to connect with their workers and farmers when arrange the stands and practices to promote social justice in agricultural sustainability (Tseng et al., 2022).

2.3.3.10. Enable Better Product and Service Provision to Customers

Digitization empowers manufacturers to analyze real-time consumer behaviour and conduct advanced impact assessments of their products throughout their life cycle (Ghobakhloo, 2020). Besides that, Industry 4.0 allows companies to innovate their business model which can promote social sustainability by provide customer with product personalization and make customer-oriented strategies (Ching et al., 2022). Additionally, this product individualization strategy can be coupled with lower cost consumer products and enhanced customer experience (Ghobakhloo et al., 2021). For instance, sensor inclusion in product enables performance monitoring, such as tracking maintenance needs, thus make companies able to proactively provide a high-quality service to customers (Lopes de Sousa Jabbour et al., 2018).

2.3.4. Negative Impact of Digitalization on Sustainability

Negative impacts refer to results or effects which are happened due to activities and/or implementation of digitalization in the supply chain processes and negatively influence all sustainability aspects (economic, environmental, and social). After reviewing the literature and grouping the facts qualitatively, it is found that there are five negative impacts of digitalization on sustainability. Those are high implementation cost, overconsumption, increase waste and pollution, reduce employment, and information exposure.

2.3.4.1. High Implementation Cost

Implementation of digital technologies may pose a challenge for small firms, specifically those with limited financial resources. Large initial investment required, and additional costs related to adoption and integration of these systems can be a barrier to small businesses. Therefore, technology such as Logistics 4.0 is suited to warehouse with high inventory turnover or product movement (Nantee & Sureeyatanapas, 2021).

2.3.4.2. Overconsumption

Despite its numerous advantages, implementation of digital technologies needs to address several challenges. As an example, blockchain should overcome its energy consumption and computation mechanisms for the complex agricultural supply chains (Pakseresht et al., 2023). Likewise, AS/RS implementation escalates electricity consumption due to rising usage of electronic machines and control systems (Nantee & Sureeyatanapas, 2021).

According to some scholars, Industry 4.0 exacerbates overconsumption and rebound effect, leading to higher rate of depletion and degradation of natural resources (Ghobakhloo et al., 2021). In addition, new devices and technologies related to Industry 4.0 need great amount of limited raw material and other natural resources, such as water and land to dispose electronic waste and reuse and recycling practices (Beltrami et al., 2021).

2.3.4.3. Increase Waste and Pollution

The rapid pace of changes and customization in electronic products may potentially lead to negative environmental consequences (Kunkel et al., 2022). For instance, replacement of AGV with autonomous mobile robot (AMR) does not significantly decrease consumption, yet it causes environmental issues due to the batteries and their end-of-life disposal (Ahmadova et al., 2022).

2.3.4.4. Reduce Employment

Industry 4.0 causes several drawbacks, such as job losses due to replacement of low-skilled labor by technology, and loss of human autonomy and control (Beltrami et al., 2021; Ding, 2018). As an example, higher degree of automation provided by 3D printing may destabilize developing countries as unemployment and social insecurity rise (Gebler et al., 2014). Likewise, use of additive manufacturing in apparel supply chain eliminates necessity for apparel manufacturers to do order subcontracting, leading to labor intensity reduction and causing negative social sustainability effect (Hohn & Durach, 2021).

2.3.4.5. Information Exposure

One of digitization's main concerns is potential risk for sensitive information disclosure (Dwivedi & Paul, 2022). Moreover, privacy is one of Industry 4.0 concern in social sustainability (Beltrami et al., 2021). Concern regarding information safety due to sharing of big data needs attention of managers (Ding, 2018).

2.3.5. Internal Contingencies on the Relationship

Internal contingencies refer to factors that may influence the relationship between digitalization and sustainability from the internal side of the company. After reviewing the literature and grouping the facts qualitatively, it is found that there are six internal contingencies on the relationship. Those are management vision, human capital readiness, infrastructure readiness, collaboration and integration, implementation strategy and reliable data.

2.3.5.1. Management Vision

The most critical challenge in implementation of sustainable supply chain 4.0 is lack of vision and strategy (Xin et al., 2022). Furthermore, Verma et al. (2022) underline that lack of top management support is the highest priority obstacle of implementing sustainable digital manufacturing. Moreover, Vafadarnikjoo et al. (2021) highlight that management commitment is one of the most critical barriers in adopting blockchain in manufacturing supply chains. In this sense, organizations should confirm top management's commitment to sustainable SCM to maintain the practice in the long run (Schilling & Seuring, 2023). In addition to that, management commitment traditionally drives organizational readiness (Beltrami et al., 2021). Meanwhile, organization's strategic orientation continues to be a concern, even after inevitable digitalization (Dwivedi & Paul, 2022). Therefore, it is important that managers should support digital transformation (Nayal et al., 2022) by delivering effective governance to prepare strategies for a smooth transition to Industry 4.0, taking in account economic, environmental, and social factor for supply chain sustainability (Luthra et al., 2020).

To overcome the previous challenges, managers should assess how to align their companies with the objectives of sustainable development and make strategic decisions for digital technologies integration and their additional measures that may be needed (Beier et al., 2022). In this case, familiarity of companies' chairpersons with the sustainability concept and align their business policies towards sustainability practices is the utmost importance (Seddigh et al., 2022). In addition, the adoption of the latest Industry 4.0 technology is strongly influenced by top management's environmental values (Zhang et al., 2021).

In the reviewed papers, there are several cases in different supply chain regarding facts about top management commitment. In agri-food supply chain, manager should recognize and select processes that will significantly impact in achieving sustainable performance (Kamble et al., 2020). In Africa cocoa industry, manager should pursue the investment and adoption of blockchain technology while also recognizes the potential of the technology to enhance supply chain efficiency and sustainability (Bai et al., 2022). In Indian logistics sector, the most essential critical success factor to implement circular economy is the commitment and support from top management for new initiatives (Gupta & Singh, 2021). In small medium enterprises (SMEs), the manager should have innovative vision and include employees and customers in the Industry 4.0 transformation strategy (Jayashree et al., 2022).

2.3.5.2. Human Capital Readiness

Lack of digital skills is one of critical barrier in digital supply chain development which urges organization to give training to their employees (Dwivedi & Paul, 2022). Besides, technophobia and resistance to change (silo mentality) can be identified as major barriers that may inhibit digital revolution (Hassoun et al., 2022).

To address previous issues, CEOs should involve people within their supply chain to harness the blockchain technology to attain successful implementation (Chaouni Benabdellah et al., 2023). To develop sustainability with Industry 4.0, people should be involved by enhancing human resource management using Industry 4.0. This can be done by increasing Industry 4.0 awareness, maintaining human capital's physical and psychological integrity, and enhancing digital competence (Torres da Rocha et al., 2022). Employee knowledge and skills in resource management is essential in the adoption of Industry 4.0 technologies and manufacturing efficiency improvement for sustainable business development in supply chain (Luthra et al., 2020). In addition, technical skills of employees are crucial element for successful integration between emerging technologies and circular economy objectives (Gupta & Singh, 2021). Informal self-education and internal upskilling initiative are several examples of preparation to adopt Industry 4.0 which can be the opportunities for universities and other education institutions (Akbari & Hopkins, 2022).

Providing training on Industry 4.0 for employees is imperative to ensure they are well-informed with latest knowledge and equipped with digital skills to tackle challenges related to technological transition (Dongfang et al., 2022; Kazancoglu et al., 2021). In the context of managing risk of data management, training and education should be provided to raise awareness about the issues, especially data privacy and security (Ozkan-Ozen et al., 2022). Environmental training for employee is also required for organization to be ready for the change and develop the competencies (Beltrami et al., 2021). Meanwhile, in the context of realizing Industry 4.0 initiative by SMEs, they must have appropriate IT resources, including managerial and technical IT capabilities for digital transformation which can be mitigated by training and technical support service providers (Jayashree et al., 2022).

2.3.5.3. Infrastructure Readiness

Lack of infrastructure and internet-based networks is one of the challenges in sustainable supply chain 4.0 implementation (Xin et al., 2022). Technological feasibility, maturity and capability are crucial barriers to overcome in blockchain deployment of supply chain (Chaouni Benabdellah et al., 2023). As an example, 3DVD design processes need internet connection, laptop and software license which requires financial resources and appropriate infrastructure (Casciani et al., 2022).

Successful integration between emerging technologies requires availability of IT-based compatible infrastructure to support the skills to reach circular economy goals (Gupta & Singh, 2021). Reinforcement of information technology systems and infrastructure is crucial as higher complexity in sustainable supply chain management reveals data security and privacy issue (Ozkan-Ozen et al., 2022). Established robust IT infrastructure and strategies are requirements to significantly impact innovation and information system administration (Jayashree et al., 2022). Development of infrastructure and IT-based facilities improves information sharing systems and resource development. This highlights that right Industry 4.0 implementation assists businesses to connect people, machines, networks, and software, leading to sustainability diffusion in the supply chain processes (Luthra et al., 2020).

2.3.5.4. Collaboration and Integration

Lack of collaboration and coordination is one of the challenges in implementation of sustainable supply chain 4.0 (Xin et al., 2022). However, collaboration between supply chain actors helps to overcome the challenge while also supports in raising transparency and decision-making in the system (Luthra et al., 2020). In the context of international food supply chains, collaboration and partnerships between firms are indispensable beside government-to-government partnerships (Kittipanya-ngam & Tan, 2020). Furthermore, collaboration with external stakeholders in the supply chain, such as government agencies, industry associations, service providers, or utility companies can help synergizing Industry 4.0 technologies within sustainable supply chain (Kunkel et al., 2022). In addition, promoting collaborative relationships with suppliers and customers by manufacturing industries which is enabled by digital technologies play an important role in managing environmental and social impacts (Oubrahim et al., 2023). Therefore, to attain sustainable supply chain management, it is vital to foster collaboration with various stakeholders beyond company boundaries (Niehoff et al., 2022).

Integration has significant impact in the relationship between Industry 4.0 and sustainability (Beltrami et al., 2021). It is also the fundamental to achieve sustainable manufacturing in the context of Industry 4.0, highlighting value chain perspective for sustainable development (Ching et al., 2022). Integration of suppliers plays important role in managing supply chain sustainability practice, especially in ensuring and evaluating their compliance to environmental and social standards while also integrating available information and knowledge (Tseng et al., 2022). Moreover, collaboration and integration between business units is a prerequisite for successful transition to a circular economy through Industry 4.0 (Kazancoglu et al., 2021). This also impacts innovation, enhances capability to effectively leverage and coordinate internal resources, while also remove functional obstacles, particularly in the Industry 4.0 era (Benzidia et al., 2021).

To do collaboration and integration, managers should focus on making collaborative relationships, sharing technical knowledge with suppliers, resulting in transparency and traceability of closed-loop supply chains (Bag et al., 2020). Manager should also engage all stakeholders across the supply chain to reach sustainable improvement with BDA capabilities which can be achieved by integrating inclusive approaches, such as circular economy and sustainable flexibility (Edwin Cheng et al., 2022). It is also important to underline that effective communication and cooperation in the supply chain influence the effectiveness of supply chain (Ding, 2018). Meanwhile, teamwork is crucial to promote information sharing and interconnectivity, leading to enhanced adaptability of employees as Industry 4.0 integrates various organizational processes and departments (Jayashree et al., 2022).

2.3.5.5. Implementation Strategy

Lack of vision and strategy is the top-ranked challenge in sustainable supply chain 4.0 implementation (Xin et al., 2022). Therefore, when adopting new technologies, companies need to build rigorous strategy to evaluate if the latest technologies are suitable for their operations (Chaouni Benabdellah et al., 2023). Moreover, strategy helps top management to construct effective approaches to plan, implement and realize sustainability objectives and goals through Industry 4.0 (Torres da Rocha et al., 2022).

2.3.5.6. Reliable Data

Lack of high existing data quality is one of challenges in sustainable supply chain 4.0 implementation (Xin et al., 2022). Furthermore, the main challenge in supply chain mapping is the organization’s ability to collect precise and comprehensive data in the whole supply chain (Chaouni Benabdellah et al., 2023). In conclusion, it is essential for organization to have comprehensive and reliable data which is available at various level within the organization (Seddigh et al., 2022).

2.3.6. External Contingencies on the Relationship

External contingencies are factors that may influence the relationship between digitalization and sustainability from the external side of the company. After reviewing the literature and grouping the facts qualitatively, it is found that there are two external contingencies on the relationship which are government / policy maker and customers.

2.3.6.1. Government / Policy Maker

Collaboration with external stakeholders in the supply chain, including government agencies support implementation of Industry 4.0 technologies within sustainable supply chain (Kunkel et al., 2022). In addition, partnerships between governments is essential in the context of international food supply chain beside collaborations between companies (Kittipanya-ngam & Tan, 2020). Therefore, policymakers have an important to advocate sustainable development of digital global value chains (Niehoff et al., 2022).

Digital technology implementations require active involvement of government entities which formulate strategic plans to guide and assist enterprises toward a better future (Zhong et al., 2017). Government entities, including universities should raise awareness about the tools and benefits of Industry 4.0 in circular economy operations which can help firms in realizing sustainable development goals and implementing Industry 4.0 advanced technology (Bag et al., 2020). Furthermore, the government should prioritize on acceptance and engagement of all stakeholders in both Industry 4.0 and circular economy to maximize the advantages of technological innovation in meeting sustainable goals (S. A. R. Khan et al., 2022). In the context of developing countries, the governments are recommended to lead the adoption of advanced technologies and circular economy in automobile and other manufacturing firms that adopt linear economy approach to promote sustainable practices in firms and environmental sustainability at national level (Yu, Umar, et al., 2022).

Absence of incentives, such as tax abatement or reimbursements hinders proactive participation of companies in sustainability participation (Ding, 2018). Therefore, Industry 4.0 should be supported by regulation that has clear targets, appropriate incentive (Beier et al., 2022), alignment with circular economy principles and focus on sustainability to create supportive environment for companies (Dwivedi & Paul, 2022). Since digital technologies implementation needs additional investments, it is crucial for governments to implement policies and encourage investments in digital technologies to promote sustainable practices (P. Kumar et al., 2022) while also encourage more environmentally friendly operations (Strandhagen et al., 2022). To support Industry 4.0 implementation across industries, it is recommended that governments make comprehensive and long-term supporting program, offer interest-free loans, tax exemptions (Yu, Khan, et al., 2022) and subsidies to encourage adoption and implementation of recycling technologies while enforce penalties, such as fines, higher tax rate, and permanent cancelation of firm registration if companies violate environmental regulations (Yu, Umar, et al., 2022). Previously mentioned policies can impact enterprises to implement Industry 4.0 technologies to minimize hazardous waste, comply with environmental laws (Zhang et al., 2021), decreasing supply chain loss and waste, minimize carbon emissions and optimizing resource usage (Ozkan-Ozen et al., 2022).

Policymakers are recommended to prioritize governmental intervention including financial incentives, legislation, eco-labels, and educational campaigns to raise users' acceptance rate of circular economy solutions. Financial incentives are important to encourage business model based on digitalization (Bressanelli et al., 2021). Specifically, tax policies can be formulated to address companies' concerns regarding the high investment costs of Industry 4.0 implementation and potential increases in electricity costs (Nantee & Sureeyatanapas, 2021). As an example, tax reductions, subsidies, or product promotions in local and international markets to stimulate their commercialization are several alternatives of incentives to companies (Dongfang et al., 2022). Subsidies on investments in digital technologies can be also applied to make digital technologies more accessible for widespread adoption (R. Sharma et al., 2020). However, companies should also put pressure on the government to secure financial incentives and support to develop more environmentally friendly products and maintain sustainable practices (S. Kumar et al., 2021).

2.3.6.2. Customers

Consumer's changed perceptions in the era of Industry 4.0 and circular economy demands logistics companies to adopt green and technical solution to meet customer expectations (Gupta & Singh, 2021). This means that customers put pressure on industrial companies which urge them to apply green practices in their businesses. However, consumers in developing economies are unlikely to pay higher price for eco-friendly products, leading to lack of financial incentives related to use of green procurement practices (S. A. R. Khan et al., 2022). This shows that customers have a power to put pressure on companies to implement an environmentally friendly practices while apply digitalization in their businesses.

2.3.7. Proposed Theoretical Framework

Based on previous findings from reviewed papers, a theoretical framework is proposed in Figure 2.7. Systematic literature has unveiled how digitalization can affect sustainability in the supply chain both positively and negatively. Meanwhile, there are also contingencies or factors that may influence the way digitalization impacts sustainability both from within and outside of company's supply chain. This proposed framework then will be confirmed and cross-checked with case studies which the details are going to be explained in following parts of this dissertation.

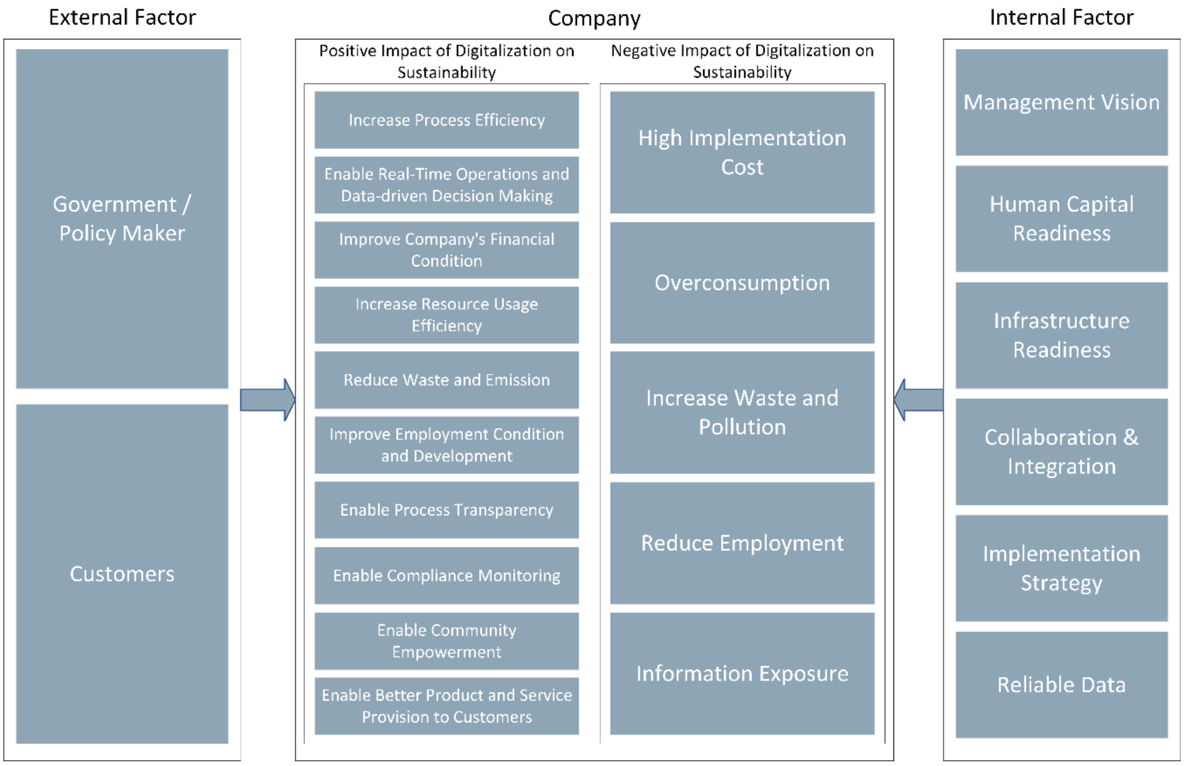

Figure 2.7: Theoretical framework of digitalization and sustainability in supply chain.

3 Research Design

3.1. Case Study Methodology

This dissertation has an exploratory nature with the aim to answer the research questions. Considering the research questions and research methodology principles by (Yin, 2018), case study will be a good method to deliver this research because:

1. The research has the objective to understand how digitalization can influence sustainability in the sustainability and the condition to make digitalization positively impacts sustainability. Since these questions are about *how*, survey method does not fit the research objectives as it does not offer sufficient depth and richness of insights.
2. Since the author has no control over companies' supply chain in terms of management and decision-making processes, the experimental method is unsuitable in this research.
3. The focus of this research, which is digitalization in supply chain, has emerged as a noteworthy trend in the business sector, particularly in recent years. Since the research focus is a contemporary event, thus historical approach cannot provide data in this research.

This research is conducted with multiple-case studies as the evidence from multiple cases is more convincing and robust (Herriott & Firestone, 1983). Additionally, Voss et al. (2002) stress that multiple case studies can help researchers to prevent observer bias, while single case study limits the theory generalizability.

3.2. Data Collection

To begin this research, a systematic literature review is done to identify positive and negative impacts of digitalization on supply chain sustainability, while recognize internal and external contingencies around the relationship between digitalization and sustainability in the supply chain, particularly in recent years. Then, a theoretical framework is made from the review. The research questions are set to investigate the relationship between digitalization and sustainability in the supply chain and internal and external factors that may influence the relationship. To confirm the theoretical framework and increase the validity, a set of questions is composed for data collection in the case study as follows:

1. How is the supply chain process of the product working from initial stage to the final stage?
2. Questions for each step of supply chain process in case companies:

a. Is there any digitalization implemented in this step of supply chain process? How is digitalization being implemented?
b. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?
c. What and how are the factors that lead to the successful implementation of this digitalization?
d. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?
e. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?
f. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?
g. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

Case study research is chosen as it allows to exploit insights from small number of cases (Yin, 2018). Furthermore, triangulation of data collection through semi-structured interview and documentation is adopted to ensure the validity, reliability, and quality of the research.

Semi-structured interviews were conducted with the management level of each case company, particularly top-level management in supply chain or production, and in business transformation or innovation. These interviews were conducted remotely in Indonesian via Microsoft Teams or Zoom. These interviews provided strategic information about digitalization and its implications on supply chain sustainability, companies' vision on digitalization and sustainability, and factors that may influence the digitalization both internally and externally.

Documentations are performed by collecting public information, such as annual reports of listed case companies, official website articles and YouTube video, and provided internal documents of each case company. Cross checking between different data sources helps to ensure data validity (McCutcheon & Meredith, 1993; Yin, 2018).

3.3. Case Selection

Regarding multiple-case study research, the case selection follows replication logic. According to Yin (2018), replication logic for multiple-case studies design means carefully selecting individual cases to either yield comparable results (literal replication) or produce contrasting result for reasonable reasons (theoretical replication), then retest the first finding by conducting a second, third or more cases. If all individual cases had the same results, they would have provided convincing arguments for the initial findings to the overall multiple case study. If the individual cases are contrasting, the initial findings should be challenged and retested with other cases. By employing both kinds of replications, the initial finding can be reinforced.

Regarding criteria in case selection, there are several criterions to ensure generalization of case study's findings (external validity) and repeatability of the studies with the same result (reliability) (Yin, 2018). First, the manufacturing industry is selected due to its implementation of digitalization and extensive research conducted on this specific industry in the systematic literature review of current dissertation. The specific manufacturing sector in this study is the fast-moving consumer goods (FMCG) companies. Second, all case companies are based in Indonesia because Indonesia is currently 16th largest economy in the world based on GDP in 2023 (estimated) and the largest economy in its region, ASEAN (International Monetary Fund, 2023). In addition, Indonesia's manufacturing sector ranks 12th in global manufacturing output (World Bank, 2022), making up 18.34% of its GDP in 2022 (estimated) as the largest economic sector in its economy (BPS-Statistics Indonesia, 2023). Due to its biggest contribution, Ministry of Industry Republic of Indonesia started an initiative of "Making Indonesia 4.0" in 2018 to elevate Indonesia to be a top 10 GDP globally by 2030 (Ministry of Industry Republic of Indonesia, 2018). "Making Indonesia 4.0" is a governmental program to accelerate Industry 4.0 technology implementation in manufacturing sector with five focus sectors which are food & beverages, textile & apparel, automotive, chemicals, and electronics. It is interesting to see how this government program impacted the mentioned industry sectors. Therefore, the third criterion is manufacturing companies which are included in the five mentioned sectors. Fourth, various product types in different cases enable to observe digitalization implications on supply chain sustainability in each case. At last, the last criterion is the different size of companies to be included in the case studies allow author to know different key internal and external factors, while also challenges and opportunities of digitalization in the supply chain (Kittipanya-ngam & Tan, 2020). Table 3.1 shows the details of each case.

Table 3.1: Case details.

No.	Product (Type of Company)	Market channel	Net Sales in 2022 (in million EUR)	No. of employee	Informants per Interview session (code)	Interview duration (hh:mm)
1.	Ice Cream (Multinational – listed in Indonesia)	Indonesia: General Trade, Modern Trade, E-Commerce; Export Market	852 [4]	4,849 [5]	1. PM Excellence & OEE Improvement Assistant Manager (OAM) 2. Assistant Engineering Manager for Electrical & Digitalization (EAM)	1. 01:38 2. 01:06
2.	Powdered beverage (Local – not listed / family-owned company in Indonesia)	Indonesia: General Trade, Modern Trade, E-Commerce; Export Market (Middle East, South Asia (excl. India), several countries in Southeast Asia, Pacific, and Africa)	233 [6]	< 1,000 [7]	1. Business Analyst Manager (BAM) 2. Production Manager (PRM) [8] 3. Former Digital Transformation Manager (FDT) [9]	1. 00:43 2. 01:11
3.	Instant Noodle	Indonesia:	2,897 [10]	34,965 [11]	1. Manufacturing	1. 01:30

[4] Retrieved from company's annual report 2022 in their Indonesian website. The number comprises all food products of the company, not just ice cream. This number includes export market.
[5] Retrieved from company's annual report 2022 in their Indonesian website. The number comprises all employees of the company, not just ice cream division.
[6] Estimated, exclude export market. Calculated from June – August 2023 net sales. Information source from company's employee.
[7] Information source from company's employee.
[8] Conducted in 2 interview sessions due to interruption in the first interview.
[9] No interview conducted, only communication through emails.
[10] Retrieved from company's annual report 2022. This number includes export market but excludes net sales of factories outside Indonesia.

	(Local – listed company in Indonesia)	General Trade, Modern Trade, E-Commerce; Export Market (International). Has several factories outside Indonesia, i.e. Middle East, Africa, and Southeast Europe.			General Manager (MGM), System Development Analyst (SDS), Central PPIC Manager (PCM) 2. System Development Analyst, Factory Manager (BFM)	2. 01:35
4.	Personal & Fabric Care (Multinational – not listed in Indonesia)	Indonesia: General Trade, Modern Trade, E-Commerce; Export Market	5,996 [12]	< 500 [13]	1. Senior Plant IT Manager (ITP) 2. IT Distributor Operation Manager (ITD)	1. 01:31 2. 01:49

3.4. Data Analysis and Coding

This dissertation harnessed two different approaches in data analysis: with-in case analysis and cross-case analysis. Eisenhardt (1989) highlights that with-in case analysis is a way to emerge individual patterns of each case, while cross-case analysis compares between cases to see if there is any similarity or difference which can lead to new findings. Doing both kinds of analyses prevents researchers from drawing premature and incorrect conclusions because of information biases. To do with-in case analysis, key information to be considered are as follow:

1. Key obstacles - to investigate, describe, and clarify the obstacles when implementing digitalization in supply chain and contributing to unsuccessful implementation if any and how the obstacles are being tackled.
2. Key enablers - to investigate, describe, and clarify the enablers when implementing digitalization in supply chain and how the enablers are supporting digitalization in the supply chain.

[11] Retrieved from company's annual report 2022. This number comprises all employees of the company, including its subsidiaries, not just instant noodle division.

[12] Retrieved from company's annual report 2022 in their US website. This number is Asia Pacific's net sales which comprises net sales of Indonesia and other countries in the region and all company's products, not just personal & fabric care.

[13] Retrieved from company's Indonesian website. This number represents total employee in Indonesia office.

3. Positive impacts - to investigate, describe, and clarify the positive implications of digitalization implementation on supply chain sustainability in terms of in terms of social, environmental, and economic aspects.
4. Negative impacts - to investigate, describe, and clarify the negative implications of digitalization implementation on supply chain sustainability in terms of in terms of social, environmental, and economic aspects.
5. Internal factors - to investigate, describe, and clarify the internal contingencies that may influence the relationship between digitalization and sustainability in the supply chain.
6. External factors - to investigate, describe, and clarify the external contingencies that may influence the relationship between digitalization and sustainability in the supply chain.
7. Future visions - to investigate, describe, and clarify the next plans of digitalization in the supply chain and how it will support the business processes in the future.

After all key information are gathered, cross-case analysis is conducted to observe the data and look for similar or different patterns between cases (Eisenhardt, 1989). Then, the analysis results are cross checked with the theoretical framework (Figure 2.7) to confirm the content of existing framework and modify it if it is needed. Case studies are employed to confirm and develop the theoretical framework.

Coding is activity of assigning meaningful labels to data segments with a code, which is defined as "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2013). The data may include interview transcripts, participant observation field notes, journals, documents, drawings, artifacts, photographs, video, Internet sites, e-mail correspondence, literature, and more (Saldaña, 2013). Coding has several advantages, including providing comprehensive insights, making data easily accessible and retrievable, organizing and structuring data, ensuring transparency and validity, and allowing voice of participants (Skjott Linneberg & Korsgaard, 2019).

Before starting the coding process, there are several steps to be taken according to Skjott Linneberg & Korsgaard (2019):

1. Define research questions and design to specify the required data in the research. This is addressed in Section 1.2 and detailed in Section 3.2.
2. Review relevant research. As stated by Eisenhardt in an article of Gehman et al. (2018), finding problems without knowing the literature is impossible. In addition, the existing literature enables developing tools for data collection, such as interview guide or coding framework. This step is covered in Chapter 2.

3. Collect data that allows systematic analysis, including textual data, such as transcribed interviews, written observations, and other text forms, as well as visual data in the form of images and videos. It is important to document them in an accessible format for labeling and long-term data retention. This is going to be covered in the next chapters.

Qualitative data coding is categorized into two types: inductive coding, which develops codes from participants' terms in the study, and deductive coding, which derives codes from existing theoretical concepts or themes in the literature (Skjott Linneberg & Korsgaard, 2019). In this dissertation, deductive coding was employed while creating the theoretical framework of Figure 2.7. based on codes retrieved from systematic literature review. Meanwhile, inductive coding will be used during case study research.

A mix of inductive and deductive coding is commonly used which is referred to as a blended approach (Graebner et al., 2012) or abduction (Alvesson & Kärreman, 2007). Skjott Linneberg & Korsgaard (2019) reported that focusing on one of the two approaches before another has different strengths and weaknesses. Inductive start ensures close connection to the data, allowing gradual evolving theory. On the other hand, deductive approaches allow structure and theoretical relevance from the beginning, with room for an inductive exploration of the deductive codes in later coding processes. In this study, the author begins with deductive coding based on systematic literature review in Chapter 2, followed by inductive coding derived from the case study research conducted in the selected companies.

4 Case Studies

4.1. With-in Case Study Analysis

4.1.1. Ice Cream Company

4.1.1.1. Supply Chain Process

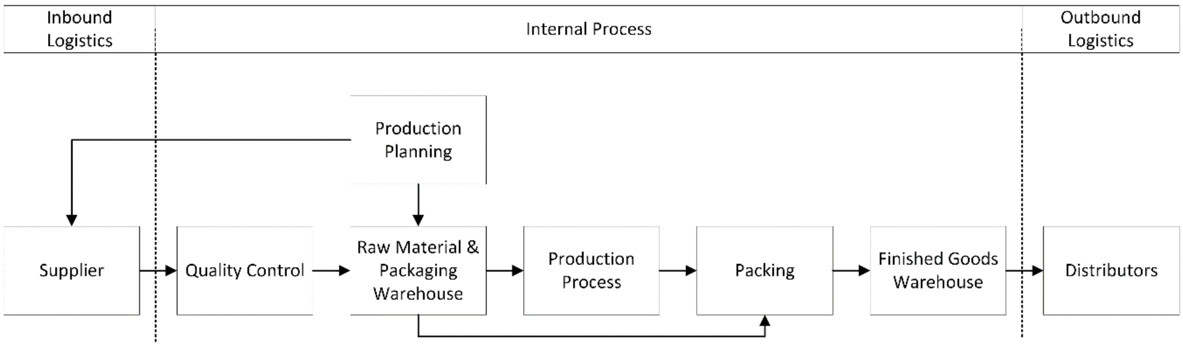

Figure 4.1: Supply chain process of ice cream company

Supply chain process of the ice cream company starts from production planning team. They place orders and purchase raw materials and packaging to suppliers through SAP Enterprise Resource Planning (ERP) system. Once these raw materials are delivered to the ice cream plant, they undergo a quality control inspection to check if they fulfil the requirements before being stored in the warehouse. Raw materials containing allergens, like peanuts, will be separated in compliance with European regulation and Good Manufacturing Practice (GMP) standards. If all raw goods meet the requirements, they are recorded in SAP system as "Goods Received". The raw material warehouse comprises three temperature-controlled rooms: multipack room is maintained at temperatures between -10°C and 10°C, ordinary storage room is kept at ambient temperature and chilled room is set to -5 C. Prior to entering production process from the warehouse, raw materials and packaging are separated into two destinations: one goes directly to production process, and the other is sent to packing hall. Packaging and raw materials intended for food outer layers, such as chocolate and peanuts are sent to packing hall, while the remaining materials are directed to the production section.

The comprehensive description of the ice cream production process in the same company can be found Liringtias' (2009) thesis and conversations with informants, outlined as follows:

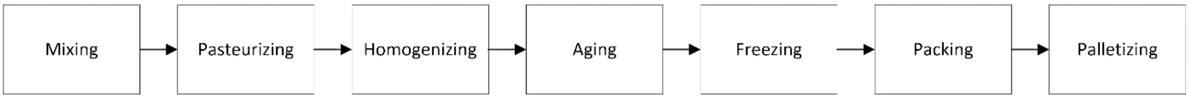

Figure 4.2: Sequence of ice cream production process

1. Mixing
   Mixing is the process of blending measured required raw materials according to the Bill of Materials (BOM). The mixture is created in a bucket, which is then placed into Mixer Tank and added with sugar according to the requirement.
2. Pasteurizing
   Pasteurizing is a process in which the mixture resulting from the previous process is heated to a temperature of 80°C for 3 seconds to eliminate any microorganism present within the mixture.
3. Homogenizing
   Homogenizing is the process of reducing particle sizes to make them uniform. The more uniform the mixture, the better its particles' ability to bind with fats, resulting in smoother ice cream.
4. Aging
   After the mixture undergoes process of pasteurizing and homogenizing, the mixture is rested in Aging Tank for maximum 72 hours.
5. Freezing
   Mixture from aging process is placed in the freezer and cooled down to a temperature between -5°C and -7°C to form ice crystal.
6. Packing
   Frozen mixture is distributed to filling machines across production lines based on specific variants. These filling machines then mold and shape the ice cream according to its various flavors and product types. In addition, packaging and raw materials for external food layers, which are separated before production section, are utilized based on the product specifications.
7. Palletizing
   Packaged ice creams from the previous process are then placed in boxes and stacked on pallets. These palleted ice cream boxes are then stored in the cold store in the finished goods (FG) warehouse.

After the production process, stored ice creams in the FG warehouse are ready to be transported to the distributors based on their demand.

4.1.1.2. Examples of Digitalization

4.1.1.2.1. Web-based Applications

The main purpose of web-based applications is to replace paper-based processes with paperless or digital processes. One of the applications is related to safety concerns, specifically a platform for reporting safety events such as near-miss incidents, accidents, or unsafe conditions in the workplace.

Another application is a platform for submitting permit to work request for contractors called Electronic Permit to Work (E-PTW). To be allowed to work in the plant, contractors must provide required documentation and obtain signatures from key persons, such as supervisor, assistant manager, and safety officer. Prior to the implementation, the process took 2 hours to complete as contractors had to locate those key individuals in different areas of the plant. This resulted in an increase of overtime budget due to this non-added value activity. Through the application, non-added value activity has been eliminated, resulting in overtime budget reduction that could have been caused by the activity.

Web-based applications are also employed to facilitate communication between the production team and engineering team through emergency work order (EWO) platform. The purpose of the platform is to inform work requests for spare parts and support from the engineering department. Before the platform implementation, the work requests were documented on paper form and required details of information about problem root causes, value analysis, and conclusion of problem causes. Furthermore, these paper documents were often not archived properly and there was an incident where piles of these papers were thrown away and seen by production operators, discouraging them from filling out the request form papers. To apply this platform, each machine in the production section is installed with tablet to facilitate production operators to report breakdown that lasts longer than 30 minutes through the EWO platform. In addition to providing previously mentioned information, operators must manually report specific time details, including breakdown time, technician waiting duration, spare part waiting duration, analysis duration, repair duration, and cleaning duration. These time data are essential for identifying potential manpower indicated by longer technician duration, detecting spare part shortage resulting to longer waiting time, and identifying major breakdown leading to extended repair times.

To simplify maintenance management in the factory, a web-based application is employed to create Computerized Maintenance Management System (CMMS). CMMS digitizes the task lists and maintenance schedules for all machines' parts. Maintenance tasks are scheduled at different intervals, such as every 3, 6 or 12 months. Prior to the system implementation, each task had to be manually managed in a calendar created in spreadsheet application This manual process was time-consuming, given the thousands of tasks that needed to be manually sorted, printed, and checked individually. With CMMS, the maintenance team input task schedule information into the database, and tasks are automatically scheduled. Moreover, these scheduled task lists can be sent to engineering team's tablets, allowing for checklist of task completion, image insertion, and recording maintenance durations, and updating spare parts inventory system. This implementation eliminates non-value-added activities of tracking and individually printing task lists.

4.1.1.2.2. Usage of PowerBI Dashboard

One of the examples is waste monitoring using PowerBI dashboard which enables to identify the production area with the highest waste from ice cream mixture processing. This waste is then weighed and converted into monetary value in Euros by multiplying waste tonnage by the end product's price. The waste's monetary value is not solely determined by its weight due to different product types and stock keeping units (SKUs). By knowing this data, the production team can identify which workstation needs improvement to minimize waste. Additionally, QR code is installed in each workstation to identify and report the origin area of the waste, its weight, and its SKU. However, the data input into the dashboard is still recorded manually using a tablet application. This data is then compiled and inputted into the PowerBI dashboard by the production section administrator. Therefore, there is a possibility of missing input data due to operator's error, resulting to data that is not entirely accurate.

Another application of PowerBI dashboard within the plant is line stoppage monitoring which allows the employees to identify machine unit that has the most loss due to breakdowns. The objective of the dashboard is to calculate overall equipment effectiveness of machines in the packing hall section. The dashboard shows percentage of target and actual breakdown, mean time to repair (MTTR) and mean time before repair (MTBR) figures on monthly and year-to-date (YTD) basis, maintenance duration, and classification of stoppage causes. By knowing those mentioned data, packing hall team can identify which machines require improvement to prevent further breakdown. In addition, if there is any recurring breakdown issue, the engineering team can follow the issue up by checking EWO platform to examine specific machine's work order record and determine the next actions. Nonetheless, the input data for the dashboard is currently collected manually on papers and compiled by a production section administrator before entry to the dashboard, potentially affecting data accuracy.

4.1.1.2.3. Usage of Programmable Logic Controller (PLC) for Automation in Machine Control

PLC has been used to control all machines in the packing hall section, utility area, and mixing section. In terms of automation, the packing hall section has only been partially automated. This is because there is a standby operator to start and stop the production line, monitoring for machine errors and ensuring products are correctly picked by the robots.

4.1.1.2.4. Remote Control of Ice Cream Cooler

The plant's ice cream cooler runs on ammonia and is managed by the utility team through Supervisory Control and Data Acquisition (SCADA). SCADA is also harnessed to regulate electricity and water within the factory. To improve SCADA control from various locations, the engineering team has developed a mobile application to control SCADA instead of using human-machine interface (HMI) on the computer. This allows the utility team not to be physically present in the utility control room. However, control permissions from mobile devices are currently disabled due to safety reasons, and users only can review the information through the application.

4.1.1.3. Obstacles and The Efforts to Overcome

As the PowerBI dashboard currently relies on manual paper recording, there is a potential risk for human errors, like incorrect input affecting the data quality. To address this issue, the ice cream plant is currently installing a new smart manufacturing system (SMS) named SMS-D that can directly extract data from machines, eliminating manual data transfer from paper to the dashboard. Currently, the project is in its pilot phase, conducting trials on one production line before full-scale implementation across all production lines. During the pilot phase, the production line being used for the pilot project is still running with the current manufacturing system named SMS-P, making redundancy. This redundancy is inevitable due to transition phase to implement the new smart manufacturing system.

Another challenge during implementation is changing users' habit from paper-based process to using handheld devices for filling application. This issue appeared during waste monitoring with PowerBI dashboard, where users were unfamiliar with the application to submit waste weight, considering the application was still in development phase. During this development stage, the developer fixed and enhanced the application based on any additional requirements and users' feedback. From the user's perspective, it took time for users to be familiar with the application. To address this issue, supervisors at each production workstation encouraged their subordinates to learn the new system and become familiar with it using a top-down management approach.

Another inevitable concern regarding digitalization implementation is increased workload for engineering team due the maintenance of additional machine. This was evident when replacing one employee in the packing hall section with a robot.

Besides mentioned obstacles, the COVID-19 pandemic also influenced implementation of smart toolbox, which aimed to track the usage and return of tools in the packing hall section. Due to COVID-19, there was a design change to add UV light for tools sterilization. However, by the time the new design was completed, the pandemic was over, and UV light was no longer necessary. Unfortunately, this delay led to increased material costs and the decision to replace with cheaper, lower-quality materials for the toolbox.

4.1.1.4. Enablers of Digitalization

According to the informants, achieving a successful digitalization implementation requires ensuring that technology solution aligns with the specific problem. In some cases, during digital implementation, they created applications that were not adopted by users because the solution didn't effectively address the problem.

Human factors also contribute to the success of digital implementation. One of the concerns is ensuring the users are familiar in using the digital system, like using tablet application to report waste weight. This can be achieved by establishing a clear standard operating procedure (SOP) since digitalization changes work culture and procedures, such as shifting from a paper-based process to using tablet application. Following that, communication to the impacted department due to the digitalization and training should be conducted to complement clear SOP to support successful digitalization implementation. For instance, training was provided to all operators in every shift to train them how to submit EWO in case of issues, which increased submission compliance.

In addition to human factors, infrastructure readiness is vital in successful digitalization. For instance, there was an incident involving an interrupted Wi-Fi network that resulted in the loss of input data for several hours, impacting historical data recording. This incident highlights the importance of having reliable infrastructure to support successful digitalization.

Apart from mentioned factors, work culture like collaboration is crucial in implementing digitalization. This became evident during the early stage of digitalization implementation, where there was a substantial amount of user feedback. Effective collaboration with a responsive contractor hired by the company to resolve this feedback enhances user engagement.

4.1.1.5. Positive Impact of Digitalization on Supply Chain Sustainability

Digitalization enhances the plant's performance in supply chain sustainability, including elimination of non-value-added activities, as observed in several cases. This became evident when applying E-PTW. It reduced time for waiting key individuals' signatures and locating those key individuals in different areas of the plant by 2 hours. Other evidence was CMMS application which eliminated activities, like sorting, printing, and checking all maintenance tasks individually. This improvement allows employees to do valuable activities like data analysis, Kaizen, and other valuable tasks. Moreover, CMMS application increased traceability of spare part usage as every spare part was registered in spare part inventory system, reducing lost spare part and enabling the tracking of spare part usage trend to identify machine breakdown issues. In addition of converting process from paper-based to digital, both mentioned applications and EWO platform prolong lifespan of documentation by storing it on the server and simplify investigations by allowing simultaneous access to the platform for everyone in case of issues thereby expediting the process.

Another beneficial effect is encouraging employees to make improvements, as observed in PowerBI application. PowerBI dashboard in monitoring waste and line stoppage were not only displaying performance, but also easing employees to identify which production workstation or machine to be improved, particularly for waste reduction, machine breakdown prevention, and OEE improvement. PowerBI also facilitated data extraction which eliminated individual data extraction from different files, saving time in the process.

Apart from mentioned benefits, PLC usage in controlling motor speed contributes to energy conservation, adjusting the electricity power and frequency to match the workload. This enables the utility team to reduce the plant's electricity consumption.

4.1.1.6. Negative Impact of Digitalization on Supply Chain Sustainability

Despite the mentioned positive impacts, there were cases when digitalization had negative effects on supply chain sustainability. Waste and overconsumption increased during the first installation of new machines, mainly due to first setup and adjustment of machine operations. For instance, a gripper machine had issues with picking up and putting down products accurately. However, this was resolved after several adjustments.

Nonetheless, digitalization has a substantial upfront investment which requires careful assessment and evaluation during the early stage of planning the project.

4.1.1.7. Internal Contingencies of Digitalization on Supply Chain Sustainability

Being a part of multinational company, the ice cream company should adhere to the directives of its global headquarters (GHQ), which follows a top-down management approach. For instance, when GHQ initiates a global project to be implemented in a specific location, such as Southeast Asia or Europe, they establish deadlines for project execution and conduct regular reviews on a monthly or weekly basis. Apart from global projects, the Indonesian HQ office urges the plant management to seek cost savings in its operations, such as reducing budget, which is stimulated by improvement projects, aligning with the Key Performance Indicators (KPIs) that must be met. In terms of operational safety, there is a standard clause from GHQ that urges the plant management to enforce specific rules. This concern is related to implementation of EWO web-based platform. The EWO platform has a critical role as it allows GHQ to evaluate capital expenditure (CAPEX) proposal, particularly for machine breakdown analysis. Failure to comply with this clause results in the proposal's disapproval. Consequently, the plant management initiates the EWO platform, establishes the guidelines and policies, and promotes adoption through training, innovation rewards and incentives to encourage people in the shop floor to be familiar with the digital platform.

Internal collaboration among the company's plants is an advantage of multinational company. For instance, the ice cream plant in Indonesia engaged in benchmarking with the plant in Turkey. The Indonesian plant sought guidance from their Turkey counterparts on implementing PowerBI in a unified platform, preventing scattered dashboards across departments. Moreover, Indonesian plant consulted with Turkish plant on improving EWO report submission compliance, thanks to the ease of sharing data for benchmarking among the company's factories.

In addition to following HQ's directives, ensuring infrastructure readiness is essential. This is particularly evident when installing tablets on each machine and setting up Wi-Fi for training on web-based platforms, such as waste monitoring, line stoppage monitoring, and CMMS. This is crucial to enable immediate hands-on practice for training participants.

4.1.1.8. External Contingencies of Digitalization on Supply Chain Sustainability

There are several parties that influence the company's digitalization on supply chain sustainability. The company considers competitors' performance as a benchmark, despite having limited data. In addition, Indonesia National Agency of Drug and Food Control (BPOM) also indirectly urges the company to digitize in documentation collection. This is because during BPOM audits, manual document compilation can be challenging if data isn't integrated. Consequently, this challenge triggers the company to consolidate documents on a single platform like SharePoint or other tools like EWO and CMMS when necessary. This need also arises during safety audits by Bureau Veritas Audit, which request documents. If the company has a centralized document storage and digital platform, it will expedite the company in providing documents to the auditors.

Regarding government involvement, the company has not received any government support for its digitalization efforts, as all initiatives are internally driven.

4.1.1.9. Future Focus on Digitalization

Concerning the digitalization focus of the ice cream company's plant, there are several key priorities. One of the top priorities is installing the new smart manufacturing system (SMS-D) which is also a GHQ project. SMS-D can directly extract data from machines and store it in servers, enabling real-time monitoring of all machines. For instance, in the event of a breakdown, the SMS-D can automatically detect it through sensors attached to the machines, eliminating manual input by the production operators. SMS-D also enables monitoring and recording process parameters, such as mixture temperature at several points, and facilitates the recording of processes executed by machines operators using tablets installed on each machine. Currently, both features of automatic breakdown detection and process parameter monitoring are currently in the development phase and have not been fully implemented yet.

Aside from SMS-D, Manufacturing Execution System (MES) is also prioritized to be implemented. MES is an integrated end-to-end platform to track goods movement from receiving raw materials until shipment to distributors which ensures the data reliability during the whole process. Moreover, MES covers maintenance and customer feedback, particularly complaints about products. Having integrated data from MES can serve as a basis for decision making, such as the development of new products. Without this system, there are challenges with data matching between different processes, such as tracking raw material usage. However, it is important to note that MES is currently not fully implemented yet.

Together with the mentioned projects, there is B-Apps, also developed by GHQ, with similar functions to E-PTW, EWO, and CMMS, which were created in-house by the plant personnels. However, the future of these self-developed platforms is uncertain due to redundancy with B-Apps. Additionally, there is consideration about whether Build Apps can effectively assist operators. Implementation of SMS-D and B-Apps has an objective of gaining Lighthouse Certification, which requires integrated end-to-end system and adopts sustainability principles in its operations. Therefore, the GHQ office urges plants in different regions to adopt SMS-D and B-Apps because digitalization is currently fragmented within the production system, and the data is not yet integrated and connected yet.

Apart from GHQ projects, the plant management aims to expand the EWO implementation beyond the production section, covering emergency work orders in the quality and safety area. In the quality domain, the platform is called Quality EWO (Q-EWO), serving as a platform for reporting quality-related incidents, such as loose bolts. Q-EWO will be digitized using the same platform as EWO since it currently reports in paper-based forms. Meanwhile, Safety EWO (S-EWO) serves to report safety incidents, like stumbling, nipped by the machine, or machine-related incidents. Currently, it also relies on paper-based forms.

It is worth highlighting that despite using top-down management, particularly in global projects of GHQ, the GHQ encourages innovation at lower level of the company. An example of this is the development of in-house platforms like E-PTW, EWO, and CMMS. However, it remains unclear when there is redundancy function between in-house application by lower level of the company and GHQ project.

4.1.2. Powdered Beverage Company

4.1.2.1. Supply Chain Process

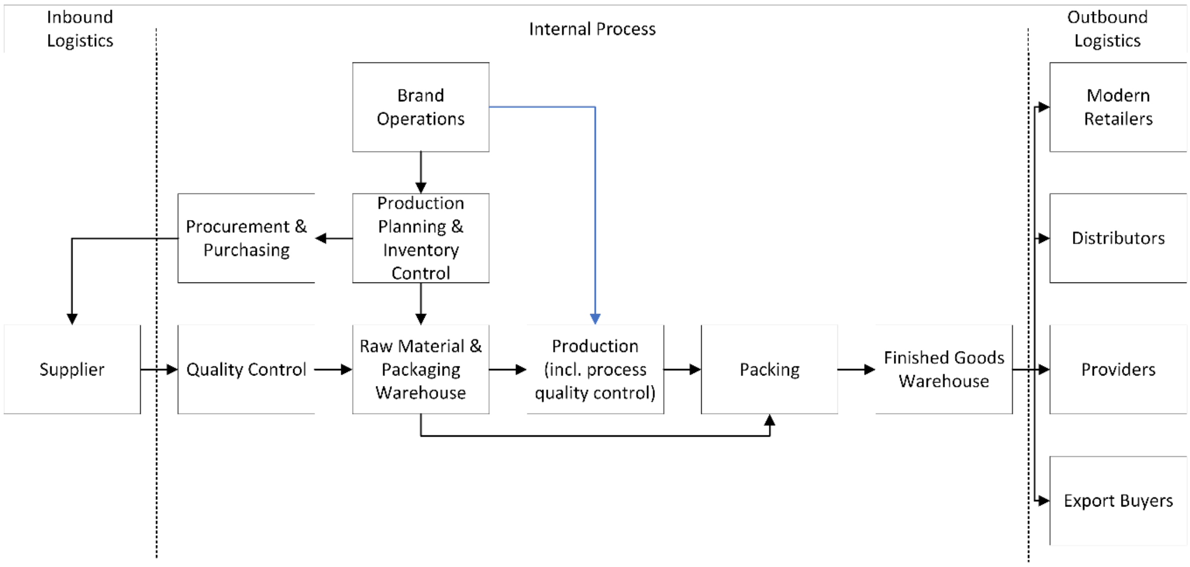

Figure 4.3: Supply chain process of powdered beverage company

Powdered beverage supply chain process begins from planning activities, specifically demand and supply planning. Demand planning is carried out by the brand operations team within the marketing division, and supply planning is the responsibility of Production Planning and Inventory Control (PPIC) team. Demand planning is placed under marketing division due to the nature of powdered beverage products, which is made-to-stock and influenced by market trends. Brand operations team utilizes market research results and historical sales data to create sales forecast covering all items and SKUs in terms of monetary value in Indonesian Rupiahs. There are two types of sales forecasts: annual forecast for year-ahead planning and used in budgeting, and rolling forecasts for ongoing production scheduling, updated monthly or quarterly. The annual forecast serves as the basis for the production team to review its annual production capacity, considering machine capacity and availability of skilled human resources or machine operators for a year-ahead. The PPIC team then translates these forecasts from brand operations team into product units and assesses the required raw materials and packaging materials for production. Following this, the PPIC team creates two documents based on the forecasts: production schedule and purchase orders for procuring raw materials and packaging materials. The production schedule is utilized by the production team, while the procurement team uses the purchase orders.

Following the purchase orders, the procurement and purchasing team's goal is to maintain stock of raw materials and packaging materials aligned with production requirements. Additionally, the procurement team looks for the raw materials and packaging suppliers and negotiates prices with them. After procurement, these procured materials undergo quality control checks before being stored in raw materials and packaging materials warehouse. Concerning the service level agreement (SLA) target, PPIC aims to fulfil 98% of orders from brand operations, while the production team aims to achieve 95% order fulfilment from PPIC team. The production team has a lower SLA target due to the presence of buffer stock in FG warehouse.

In the next step, the production team follows the production schedule to produce finished goods. During the production process, there are several quality control checkpoints to monitor the production process. After production, finished goods are transferred to the FG warehouse, which serves three main functions: receiving the production output, managing inventory, and delivering finished goods accurately, on time, with the right quality. The warehouse has four types of customers to be served: modern outlets, distributors, providers, export buyers.

1. Modern retail outlets in the Greater Jakarta area and Bandung are directly served by the company's distribution center.
2. Distributors cover both traditional markets and modern retail stores according to their respective regions.
3. Providers, like distributors, are managed directly by the company. Although there is a third-party partnership for the provider's management, these providers manage the warehouse operations, orders, and inventories by using the company's warehouse management system.
4. Export buyers are customers dealing with finished goods intended for export.

4.1.2.2. Examples of Digitalization

4.1.2.2.1. Digitalization along The Supply Chain

In the procurement process, the company has established a platform where potential suppliers can submit tenders, the required documents, and complete their profiles. It is important to note that the platform is not publicly accessible and is exclusively shared with potential suppliers.

Upon the arrival of raw materials, they will be registered to warehouse management system (WMS) to track both inbound and outbound raw materials. WMS is integrated with the Oracle Inventory System. Meanwhile for office supplies, machinery, and item purchases, there is a digital Asset Enterprise Planning system. Communication between office users and the procurement department from placing orders to completing procurement process, is simplified through a dedicated digital platform.

In production, the company employs a weighing application to verify raw material weight matches the pre-inserted formula. Regarding product formulas, there is a formula management system to manage all products formulas, including current ones, past formulas, alternative formula, and substitute raw materials. This encompasses database management and its associated processes. Similarly, packaging has its own dedicated management system. All these management systems are integrated with Oracle Production and Inventory System. For managing outbound goods, the company utilizes Oracle Order Management, which controls the entire process from order placement to the outbound process.

4.1.2.2.2. Manufacturing Execution System (MES)

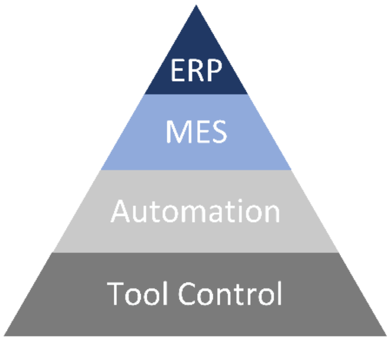

Figure 4.4: Automation pyramid

The powdered beverage company's production department consists of five internal production teams dedicated to each of company's five plants, along with one toll manufacturing team. Since 2015, the production team has been working on a project to establish a Manufacturing Execution System (MES), which is applied across all internal production teams. In implementing digitalization within the production process, the production team follows the Automation Pyramid concept which is shown in Figure 4.4. To implement the concept in digitalizing the production process, it does not require fulfilling all lower levels below MES because the company has already implemented an ERP system by Oracle over the past 20 years.

In implementing the MES, the chooses to develop its own MES. Despite there are many third-party vendors that provide MES solutions, it is challenging to effectively integrate the system within the company. Hence, developing an in-house MES allows for adjustments to align with the company's unique business processes and specific requirements.

MES is designed to digitally capture real-time physical activities occurring on the shop floor, including the actual process runtime. For instance, if it takes 10 minutes to produce product A, the MES system records the actual runtime observed on the shop floor. To make it happen, MES relies on operational technologies (OT), which is hardware embedded in machine for data collection, and information technologies (IT), which is application in the production process for MES. Both components need synchronization through intermediary software. Prior to implementing MES, the company relied on paper-based recording process to document runtime and downtime information. Analyzing this data required a time-consuming process of manually extracting information from these paper records. Consequently, the company should convert paper-based recording process to data input on tablets gradually because in MES, data is directly collected from machines into the system without any manual input from humans. Currently, the company has already implemented a smart manufacturing system to extract machine performance data, including runtime and production outputs. This smart manufacturing system made the company receive recognition from the Ministry of Industry as an Industry 4.0 technology-ready company. (Ministry of Industry Republic of Indonesia, 2021b).

4.1.2.2.3. Robotic Process Automation (RPA)

The company employs RPA to decrease manual work by employees. One of the implementations is automating order placements from the B2B market, particularly a modern retail company. The RPA extracts data from the specific modern retail company's website where they submit orders to manufacturing companies like the powdered beverage company. This order information is then transferred to the powdered beverage company's Oracle system, registering it as a purchase order from the modern retail company. Subsequently, this order is received by FG warehouse and dispatched to distributors and outlets that previously placed orders.

4.1.2.3. Obstacles and The Efforts to Overcome

Prior to executing the digitalization, the company conducted benchmarks by examining several cases of digitalization. In the company's case, the company chose to begin by developing the IT system. During the implementation of digitalization in the company's production department, several challenges have been identified by the informants.

One challenge involves designing an application that perfectly captures the business processes on the shop floor and translates them into a functional application model. For instance, in the production of product N, the scheduling and production sequence must consider optimal combinations for product container washing, minimizing the number of washing processes. Additionally, each variant of product N has its own unique production sequence, which entails customization in the application design. To address these complexities, a business analyst with a deep understanding of the shop floor's physical activities is critical to ensure a close alignment between the application and the actual shop floor activities. Furthermore, the application should remain flexible, as it could become impractical if it is overly rigid. To achieve this, the production manager forms a collaborative team, comprising IT developers and users. The IT team is from external to the production team and includes a business analyst, who acts as an integrator and has a deep understanding of the actual business processes on the shop floor, and a developer, who possesses programming skills to translate shop floor activities into application code. On the other hand, the users consist of production team supervisors and administrators who are responsible for inputting runtime data from paper records.

This team composition aims to ensure that all details of shop floor processes are accurately depicted. To maintain alignment and progress, the team conducts biweekly meetings with the production manager. During these meetings, the business analyst analyses the actual business processes while the user confirms the results of the analysis.

Educating people on the shop floor is another challenge in the execution. While the IT team has developed an application that closely reflects the shop floor's business processes, the issue lies in training shop floor employees to effectively use tablets. The younger shop floor workers tend to be more tech-savvy and adapt to these devices more easily. In contrast, senior employees often struggle with tablet usage, finding it confusing to operate the touchscreens. To address this challenge, the HR team created a comprehensive training program focused on digital awareness. The objective of the program is to familiarize employees with computers and digital tools through online, self-service training modules. Apart from HR training, additional training sessions from the IT team are conducted when the application is ready for use. During the initial phase of application usage, a one-month "babysitting" phase will be implemented where business analysts accompany users during actual production processes. In cases where there are multiple work shifts, the business analyst is available during each shift to receive user feedback and provide immediate solutions if bugs arise during implementation.

Another potential challenge is the synchronization of OT and IT due to the wide variety of ages among production machines. The company's machinery includes both very old and brand-new machines, and not all machines are ready to do data acquisition. Therefore, the key challenge is to ensure that all machines are ready for data acquisition and that acquired data can be stored within the application. Additionally, ensuring the validity and cleanliness of the data for analysis presents a different obstacle. To tackle these challenges, the company requires experts to provide guidance on data acquisition methods and types of hardware that need to be prepared.

Resistance from employees was encountered during the implementation of RPA. Many employees expressed concerns, complaining about robot crashes, even when the issues were minor and easily solvable. Some employees were reluctant, fearing being replaced by the robot. Consequently, they continuously raised concerns about its reliability and the need for improvement of the robots. Addressing this resistance took several months to familiarize employees with the implementation. The implementation resulted in a reduction in employees, with some employees retained to ensure the robot's seamless operation and address any issues. To address this resistance, the higher management backed the RPA usage and the manager who used the RPA verified the reasons behind the issues, which were often related to user actions. Employees were also re-educated on the system and provided reassurance from the top management, convincing them that the system was functioning effectively. Eventually, employees were convinced to collaborate with the machine.

Another challenge arose during the implementation of the demand planning forecast feature in Oracle ERP system. Instead of using the forecast feature, the brand operations continued to manually input their own forecast figures. These manual interventions were necessary to account factors that could not be captured by historical data and forecast, relying on intuition based on individual knowledge and experience. In addition. Some of the manual inserts aimed to focus sales programs on specific regions. Consequently, the application was underutilized, and the brand operations team opted for Excel application which met their needs, resulting adjustment of machine-generated forecasts with these manual inputs.

4.1.2.4. Enablers of Digitalization

Ensuring alignment between application requirements and the specific problem it addresses is essential in determining the benefit of the application for the company. In addition, conducting cost benefit calculation is crucial to assess the project's economic feasibility. To ensure a successful digitalization, particularly in the production process, an application must accurately reflect every detail in the actual business processes. Moreover, it should be flexible to accommodate new product developments in the future. Otherwise, it may become impractical, resulting in reverting to paper-based recording for production data.

Top management support plays a crucial role in enabling digitalization, encompassing financial backing and assistance in addressing employee resistance. Furthermore, top management should possess a clear understanding of the objective of each technology implementation, the designated timeline of the implementation, and the potential trade-offs when adopting new technology. For instance, RPA implementation had to sacrifice several employees as the technology replaced certain roles.

The readiness and mindset of the employees are another key factor in enabling successful digitalization. If employees are reluctant to learn to use the application, they may revert to paper-based processes. Therefore, a willingness to change and open-minded characteristics are essential for the employee. Apart from readiness and mindset, employees who utilize the new technology should have a deep understanding of the business processes and their objectives. In the RPA case, the aim was to eliminate all repetitive processes and delegate them to robots. When users have a clear understanding of the system's objectives and capabilities, they can effectively harness the technology without the IT team support.

During the technology implementation, it is crucial to maintain team engagement to ensure their commitment to the project. Similarly, maintaining a dedicated IT team for the project is equally important. Frequent IT team rotations to other projects can result in delays as it disrupts the learning curve related to the new business processes.

The robustness of the system and its hardware components is another critical factor. Too many software bugs can hamper successful implementation. Additionally, hardware sensors that do not function as expected can also pose problems.

4.1.2.5. Positive Impact of Digitalization on Supply Chain Sustainability

The powdered beverage company experienced several positive impacts on its sustainability due to digitalization.

On the operational side, having access to more valid and real time data allows the production team to comprehensively analyze all conditions in the production process, particularly in addressing downtimes. The goal of these analyses is to improve productivity and reduce costs. In the finance department, a digital platform has been introduced that allows users to digitally sign documents using a secure token, ensuring both security and legality of the signatures. This eliminates the need to locate individuals for document signing, saving time and effort.

Apart from the operational advantages, digitalization in the company indirectly affects the eagerness to learn about technologies. Furthermore, innovation challenge events in the company also increase awareness about technology, inspiring the employees to integrate technology in their job.

In the environmental domain, the adoption of tablets for recording production data in the production process and the integration of applications with the Oracle ERP system have reduced paper usage as all data is now stored in digital formats on servers. In addition, the ongoing implementation of the best route algorithm within the sales division has resulted in reduced pollution and lower fuel costs. The forthcoming digitalization initiative in this domain involves tracking packaging waste before it is sent to small and medium enterprises for processing into more valuable products.

4.1.2.6. Negative Impact of Digitalization on Supply Chain Sustainability

Apart from mentioned positive impacts, it is important to highlight the high cost to develop digitalization. To anticipate the high implementation cost, it is crucial to ensure that the developed application aligns with the requirements, that the users have eagerness to learn and change, and that all hardware and software are robust to support digitalization. Additionally, another challenge relates to investment required for processing power and security, demanding the need for additional human resources to maintain the application.

In social domain, digitalization reduces manpower, especially due to elimination of menial and repetitive works. To address this, there are several work processes that employ non-permanent workers. The goal is to avoid layoffs of permanent employees when implementing digital solutions. In the case of the production department, the production manager assessed how many employees can be retained, considering permanent workers, as digitalization was implemented. In the RPA case, there were a few layoffs and non-renewal of some contracts. To address this issue, new roles were created for affected permanent workers, and training was provided to enable employees to collaborate with the robots. There is also a concern about reduced critical thinking among employees due to over-reliance on technology, following system interfaces rigidly. To mitigate this, the manager encourages subordinates to give suggestions for process improvements.

During the digitalization implementation, a temporary decrease in production output may occur due to inevitable transitional stage of application usage, including structured training and babysitting period to ensure user familiarity with the new system and promptly address issues by the development team. This transition is essential for long-term productivity gains.

Aside from the mentioned concerns, digitalization implementation leads to higher electricity costs and processing power. In the RPA case, robot applications consume electricity, but the economic benefit outweighs the associated electricity costs. However, there is no specific measurement provided for the electricity consumption according to the informants.

4.1.2.7. Internal Contingencies of Digitalization on Supply Chain Sustainability

As with any organization, top management holds an important role in directing the company. Over the past five years, the CEO has promoted digitalization within the company, encouraging the middle management to integrate their operations with digital tools. This has led to accelerated digitalization, particularly in various departmental business processes, albeit on a smaller scale. Moreover, regarding ERP implementation, the company initially adopted Baan's ERP system back in 2000 and later transitioned to Oracle in 2010. These initiatives were driven by the top management's goals to improve efficiency, stay current with technology development, expedite data retrieval, and streamline reporting processes.

To derivate the top management’s goals, the company annually formulates a strategic plan with specific objectives. This strategy is then broken down into sequential actions, creating a comprehensive architectural framework to ensure organized and integrated data management. Furthermore, each division is tasked with creating an annual blueprint that elaborates their digital development plans for the upcoming year, focusing on the anticipated benefits. These plans undergo a thorough cost-benefit analysis to determine their feasibility and potential inclusion in next year's blueprint. If approved, the necessary resources, including funding, human resources, and infrastructure, are allocated for plan execution. Additionally, the return on investment (ROI) for each project is calculated to ensure a comprehensive understanding of its potential value.

In addition to careful planning before digital implementation, the company embraces innovation as their work culture, promoting continuous learning and improvement among employees within their respective departments. To foster this culture, the company hosts innovation showcase events that trigger employees to revisit their processes for potential digital improvements. In addition, the HR team supports the culture through digital awareness programs.

In summary, top management's direction, work culture and HR initiatives collectively support the digitalization implementation within the organization.

4.1.2.8. External Contingencies of Digitalization on Supply Chain Sustainability

In driving digitalization, the company evaluates external technology developments for potential implementation, considering benefits and stability. These include interactions with suppliers who offer services and products to support digitalization efforts. To develop applications, the company collaborates with freelancers who are partners with a deep understanding in the company's project execution.

Regarding government involvement, the company earned recognition from the government for its readiness and commitment to adopting Industry 4.0 technology. The government, specifically the Ministry of Industry, offers training and consultancy to support the initiative (Ministry of Industry Republic of Indonesia, 2021b). To access this government support, the company had proactively built a network with the industry community, including technology vendors like Schneider Electric, as per information from the company's former digital transformation manager.

In addition, foreign entity also plays role in the company's digitalization journey. In 2019, the company was assisted by GIZ, a German international development agency and the Ministry of National Development Planning to develop data science skills of the employees by providing training for selected employees and guiding them to replicate the training in the company (GIZ, 2019; Ministry of Industry Republic of Indonesia, 2021a).

When it comes to the broader market, the company evaluates both customers and suppliers. For suppliers, the company considers external factors such as global economic and geopolitical conditions, like the impact of events such as the US-China trade war on the material supply routes. In terms of customers, while not directly linked to digitalization, encourages the company to enhance processes for improved data accuracy and traceability to address issues. Additionally, the company adapts to changing customer shopping habits by expanding their presence in various online marketplaces through the e-commerce division.

4.1.2.9. Future Focus on Digitalization

The future focus of the company's digitalization aims to enhance efficiency, productivity, and data integrity while reducing cost. These initiatives are expected to foster better collaboration through more integrated data and gain better economic performance through faster data retrieval. In addition, it is important to underline that the company's primary objective on digitalization is to enhance its business operations from an economic perspective, with the positive environmental effects being a consequence, not the central focus of these efforts.

4.1.3. Instant Noodle Company

4.1.3.1. Supply Chain Process

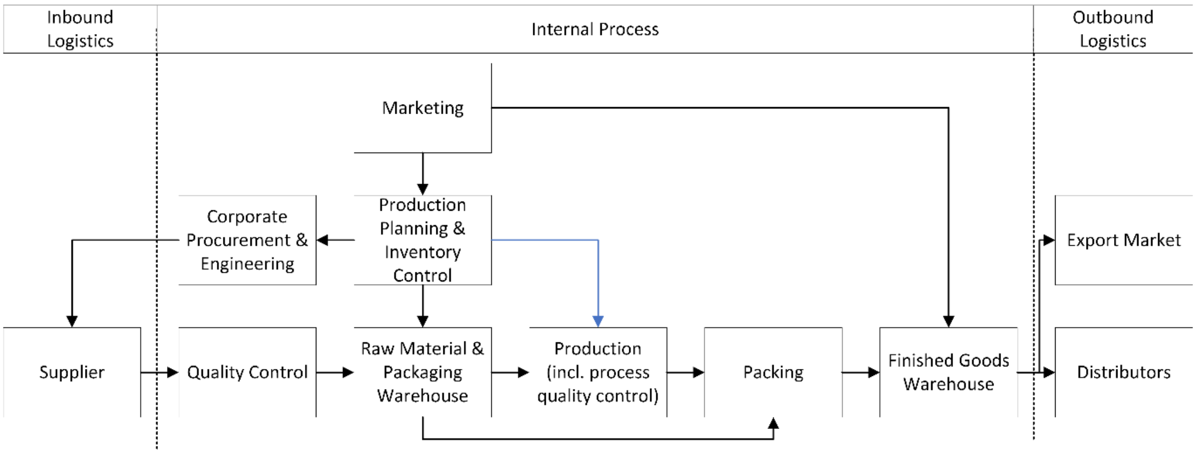

Figure 4.5: Supply chain process of instant noodle company

Instant noodle supply chain process commences with planning from the marketing team, which provides confirmation of weekly forecast (CWF) based on market conditions. This CWF is recorded in SAP ERP system and becomes the basis for the PPIC team, who then calculates Master Production Schedule (MPS) to get Materials Requirements Planning (MRP) in SAP system. This calculation specifies the required raw materials for each product's bill of materials (BOM). Buffer stock is also added to anticipate potential sales increases. Once the MPS is complete, purchase requisitions are released by both branch offices and head office due to variations of SKU-specific demand. The head office, specifically the corporate procurement & engineering (CPE) division, manages the supply allocation of raw materials from various vendors, including both company-owned and external suppliers. In addition, the CPE division also considers factors like proximity between factory and suppliers, competitive pricing, and vendor availability. The goal is to achieve operational efficiency. Raw material suppliers receive purchase orders and produce the necessary materials, which are then transported to the designated factories in line with the MPS MRP calculation.

Upon the arrival of raw materials at the factory, raw material trucks and its drivers are checked for licenses, cleanliness, and any oil drips, in compliance with health safety environment (HSE) and halal standards. Once checks are complete, trucks are allowed to enter. Quality Control (QC) team verifies raw materials, issuing release document for verified items stored in the warehouse or silo for flour.

Before starting the production process, PPIC plans a daily production schedule based on marketing team orders in SAP system, automatically calculating raw material needs and prompting warehouse supply. Production begins, and results are transferred to the FG warehouse.

To deliver the product to a specific destination, marketing team issues a delivery order to the finished goods warehouse. When goods are loaded onto trucks, goods issued will be registered in SAP system records as "Goods Issued" upon departure from the warehouse.

4.1.3.2. Examples of Digitalization

4.1.3.2.1. Truck Queueing System (TQS)

Truck queueing system (TQS) manages truck entry and exit queue, monitors trucks' movement in the factory and position, and ensures truck registration on both unloading raw materials and loading finished goods. TQS is crucial for food defense, protecting food products from contamination. TQS verifies the truck and driver registration, maintaining security and communication with vendors regarding the delivery details. It allows prioritization for trucks that deliver urgent raw materials for production. Fingerprint is employed to simplify entry process for registered drivers to enter the factory. Before using fingerprints, the first development of TQS used semi manual way due to difficulty to change organizational habit, adopting incremental approach alongside the suppliers.

When delivering finished goods to distributors, TQS platform registers delivery order from the marketing team and applies same checking procedures, including license, truck type, and oil drips, to the delivery trucks.

Apart from the mentioned features, TQS is integrated with the SAP system and E-Purchase Monitoring (EPM). Integration between TQS and SAP system enables direct "Goods Received" registration in the SAP system when weighing truck delivering flour in weighbridge. Meanwhile, integration between TQS and EPM enables real-time tracking GPS position of the trucks delivering raw materials by the factory team, currently applied only to company-owned transporters, with mobile device monitoring capability.

4.1.3.2.2. E-Purchase Monitoring (EPM)

E-Purchase Monitoring (EPM) manages factory's purchase orders to the non-company owned suppliers, including submission of required documents and its delivery plans on a designated website before suppliers supply their raw materials to factory. This platform was created due to no SAP system connectivity with non-group vendors. It serves to monitor raw material deliveries and assess supplier delivery times. Failure to provide required documents prevents "Goods Received" registration in the SAP ERP system, promoting vendor discipline in data submission. The platform includes a quality feature that limits arrival time of raw materials based on production dates, requiring central quality control (CQC) approval if exceeded. Additionally, EPM handles purchase rescheduling, delays, and order diversions for non-group third-party vendors, while SAP manages these needs for company-owned vendors. In addition, the implementation of EPM used an incremental approach because the implementation needs to work together with the suppliers.

Aside from the mentioned functionalities, EPM is integrated with both TQS and SAP system. Integration between EPM and SAP system allows non-group vendors to monitor their trucks once they report to the factory's security via TQS platform. The details of EPM and TQS integration are explained in the previous TQS section.

4.1.3.2.3. Features of Auto-Recording and Digital Approval of SAP ERP System

Auto-recording in SAP ERP system automates goods movement registration by fingerprint or machine-attached sensors. Fingerprint registration is used in QC raw materials release. Sensor-based automation tracks goods movements in processes, such as flour weighing, "Goods Issued" for flour from silo system to production process, "Goods Received" for finished goods transfer to FG warehouse, real-time recording production process parameters like machine and process temperature, pressure, speed, and process time. These parameters recording supports process improvement and early warning system via statistical process control for troubleshooting, replacing the previous paper-based process.

In addition to auto-recording feature, digital approval is employed for cases where raw materials exceed the time limit for use in the production process. This allows tracing and adding notes for approval. Supporting data for digital approval can be extracted from SAP, so there is no more data entry, automatically shown by system from SAP system, eliminating input errors. Currently, digital approval is developed only for return confirmation with suppliers.

4.1.3.2.4. Automatic Daily Report

Automatic daily report is an SAP system feature that generates daily report generation on finished goods stock, daily sales, raw material stock and fuel stock. This feature utilizes business intelligence and automatic email delivery, providing managers with the same resource of data for quick decision-making. In addition, it enhances the effectiveness of weekly production coordination meetings, reducing disagreements from different analyses. Meetings now average 30 minutes to 1 hour, positively simplifying the work processes.

Previously, a dedicated person manually extracted and compiled the data from SAP system into Excel application before sending it to managers.

4.1.3.3. Obstacles and The Efforts to Overcome

Human factors are the foremost obstacle in the digital implementation in the company. This includes changing user habits from paper-based processes to digital methods, requiring data entry, monitoring, and integration through the system. Moreover, the workforce's digital skills and capabilities vary in different factories and there is reluctance from some users during the implementation.

To address the human factor issues, the company adopts an incremental approach, gradually improving the execution. For instance, TQS implementation began with a semi-manual way before changing to fingerprint scanning. Similarly, auto-recording implementation in the production process started with one production machine, allowing users to adapt through trials and training. Another instance was halal requirement introduction in EPM platform after successful implementation of raw material time limits. In addition, a manual book is provided to guide the implementation. Alongside the incremental approach, a change management concept is introduced, involving gathering, briefing, and informing the users before conducting trials with the new system. Lastly, the leadership of each supply chain section leader plays a crucial role in convincing their subordinates to adopt new digital technologies.

4.1.3.4. Enablers of Digitalization

As a vertical integrated company, alignment with parent company's vision is essential for every digitalization program in each supply chain part. Prior to digital implementation, the concept of the digitalization program had been discussed between factory and head office, eliminating different goals of the project.

Effective leadership is required in driving implementation in each supply chain unit. Regardless of the complexity of a project, a leader's decisiveness is key to success. In addition, it's essential to form a project team that understands the process thoroughly.

In terms of project execution, it is essential to have the same implementation concept between vendors and the factory. The factory team explains the business processes, while vendors convert them into hardware and software configurations for digitalization. Discussions regarding adjustments and alignment of work instructions after digital implementation are required with the production, engineering, and quality control teams, considering factors like maintenance processes, sanitation, and data analysis requirements.

Aside from the mentioned factors, maintaining consistency among users who operate the system is equally critical to ensure its expected and consistent functioning. Hence, training before implementation and ongoing evaluation are crucial to keep the digitalization on course.

4.1.3.5. Positive Impact of Digitalization on Supply Chain Sustainability

The implementation of digitalization in the company has brought about several benefits. TQS, EPM and auto-recording of production process parameters make operations easier to monitor from any internet-connected devices, eliminating the need for physical control. Moreover, integration between EPM and SAP enables non-group vendors to monitor their trucks. This ease of observation and monitoring enhances the process evaluation for faster decision making, enabling easier improvements in processes, resulting in better efficiency, reduced waste, and increased production outputs. In addition, automatic recording minimizes human error, and data is securely stored on a server, accessible only to authorized employees.

In addition to a more transparent process, introduction of sensors in the production process allows the production team to identify areas for potential improvement in electricity consumption through data provided by these sensors.

Digitalization also embraces paperless operations within the company. Purchase orders from vendors are no longer printed because the orders are directly managed in the SAP system for company vendors and through the EPM platform for external suppliers. This eliminates human errors caused by misreading paper-based purchase order tabulations.

Furthermore, digitalization improves productivity in the supply chain. In the production process, various tasks are handled by machines or automation systems, reducing human intervention. To address the potential negative impacts on employees, those affected by the automation are relocated to other departments. In addition, SAP-generated reports simplify data extraction and analysis, leading to more effective meetings with fewer arguments resulting from different data interpretations.

Digitalization enhances communication among departments. The integration of EPM, TQS, and SAP system results in improved communication between departments within the factory, including security team managing arriving trucks, QC team inspecting delivered materials, warehouse team receiving materials, and PPIC planning materials for production.

Apart from the mentioned advantages, the digitalization projects encourage young employees to contribute to the company’s digitalization according to their positions.

Moreover, the project also stimulates the IT division to increase and develop their skills.

4.1.3.6. Negative Impact of Digitalization on Supply Chain Sustainability

The company has not experienced any adverse effects from digitalization in its supply chain. However, the initial high investment cost is a potential concern, which can be addressed by conducting an economic calculation to determine the payback period and return on investment. Reducing employment is another concern, which is addressed by transferring affected employees to other departments.

4.1.3.7. Internal Contingencies of Digitalization on Supply Chain Sustainability

Top management has a crucial role in driving digitalization as they set the direction of the company and challenge the middle management to improve productivity. The commitment of middle managers to continually improve their performance aligns with the top management's initiatives.

To complement the top management's initiatives on digitalization, a careful annual plan is conducted. Each project goal that emphasizes innovation, efficiency, and effectiveness improvement is carefully evaluated and checked regarding the requirements, costs, timelines, methods, and responsible parties. All project-related details are outlined in both short and long-term plans. Once these project details are justified, funding approval is obtained from top management.

In addition to careful planning, project approval processes are conducted sequentially, involving the internal manufacturing team, division head meetings, and board of directors. Once the key stakeholders approve the plan, capital expenditure approval is granted, and the projects are executed. To control the projects, progress on these plans is regularly reported to relevant stakeholders.

4.1.3.8. External Contingencies of Digitalization on Supply Chain Sustainability

Engaging with external vendors and attending technological fairs keep the company updated with recent technology developments. This engagement involves inviting competent vendors in automation to share insights on technology development. Overall, it helps the company align with current technology trends and enhances its supply chain sustainability.

In terms of government involvement, the company has not received any support from the government in its digitalization journey, as all initiatives are internally driven.

4.1.3.9. Future Focus on Digitalization

The company's next digital development focuses on leveraging current projects to improve cost efficiency and profitability. This includes automatic SAP system registration for frying oil, eliminating manual registration. They also aim to integrate digital approval and halal transport requirements with EPM platform to streamline the existing process and anticipate government regulations for halal transport certificates. Additionally, real-time GPS tracking is also planned for non-group vendors, although it depends on the transporters' willingness to invest and head office approval.

4.1.4. Personal & Fabric Care Company

4.1.4.1. Supply Chain Process

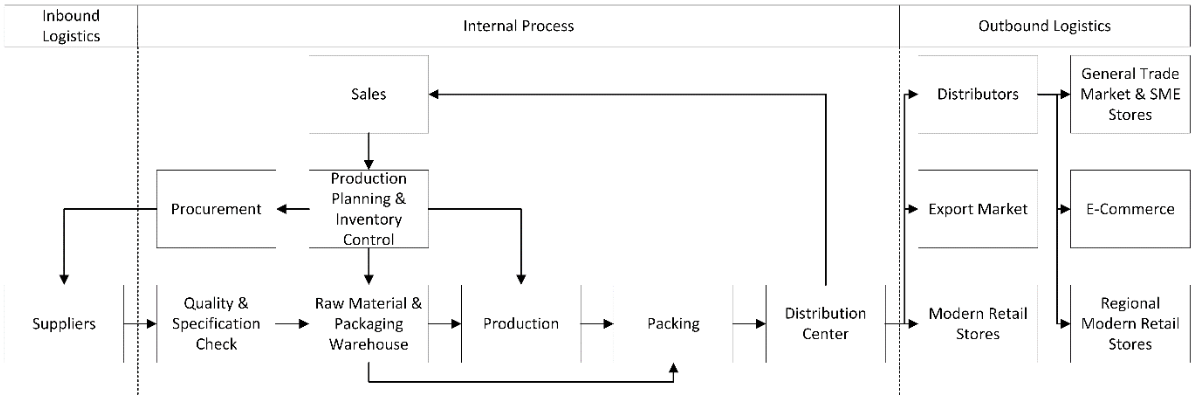

Figure 4.6: Supply chain process of personal & fabric care company

The supply chain process of the personal & fabric care company starts from the distribution center providing demand forecast to the sales team. The sales team forwards this forecast to the PPIC team, which translates it into raw materials and packaging purchase orders for procurement team, transfer requests for warehouse team, and production schedules for production team. To minimize inventory costs, raw materials and packaging are supplied using a just-in-time (JIT) approach. Prior to entering the warehouse, incoming raw materials and packaging are checked for quality and specification, including halal certification for materials from abroad. Some liquid raw materials are immediately directed to production lines, while the majority are stored in the warehouse.

The Indonesian plant manufactures two types of products which are shampoo (hair care) and fabric enhancer. Each product type has its own production line due to differences in the nature of processing. Hair care production follows batching system, while fabric enhancer production operates continuously. When the production process is complete, the product is temporarily stored in a withholding tank. Once the packing system is ready, the product is transferred from the tank to the packing area.

In the packing area, various machines are used depending on the product's packaging format, including small and large sachets and bottles. The packing lines are not specific to hair care products. Following the packing area, there is an "end of line" section where contract workers gather & prepare cardboard boxes on pallets.

After “end of line” section, palletized finished goods are transferred to the adjacent distribution center (DC) within the plant area. This DC serves as a storage facility not only for finished goods from the plant, but also various company products from different sources. These products include imported company products such as razors, items from contract manufacturers like cough syrup drug, and multivitamins.

Once the finished goods are stored in the DC, they become available for sale to distributors. In the distribution process, the company directly sells products to modern retail groups and exports to various countries such as Thailand, the Philippines, and Australia, ensuring compliance with each country's product standards. Other distribution activities are managed by distributors.

Distributors handle three types of clients which are e-commerce, general trade market (GTM) and small medium enterprises (SME) stores, and regional modern retail (RegMR) stores, each with different distribution policies. E-commerce distribution is managed by a third-party distributor with a partnership agreement. The distributor maintains stock levels based on sales history and delivers products to the customers according to their delivery area.

Figure 4.7: Indonesia map. Source: Wikipedia

For GTM, SME, and RegMR stores, distribution is managed by regional distributors across provinces in Indonesia. Distribution policies differ for Java Island and areas outside Java due to geographical conditions as shown in Figure 4.7.

1. For distribution in Java, orders from stores are received on D-0 and processed in the company’s DC the same night. Next morning, products are sent to the distributors’ DCs, and delivered to stores in the afternoon. By D+2, items are available in stores.
2. For distribution outside Java, orders from stores are received on D-0 and processed in the company’s DC the same night. On the following morning, products are sent to the distributors’ DCs, which can take between 3 to 12

days due to sea and land transportation. Ordered items are delivered to stores starting the day after they arrival in distributors' DC. Items are available in stores between D+5 and D+14.

These longer delivery times outside Java can occasionally occur in out-of-stock situations.

4.1.4.2. Examples of Digitalization

4.1.4.2.1. Digitalization related to Suppliers

In the effort to digitalize the company's interactions with suppliers, the company introduces a platform for material certification uploads, eliminating manual checks on certificates individually. After the implementation, the procurement department simply reviews the documents through the system and approves the material if the certification is in order. Furthermore, the company assists suppliers in enhancing the quality of critical raw materials, as the quality of these materials directly affects the company's products. To ensure quality control, the company adopted Process Control Strategy (PCS) that monitors various production parameters. By ensuring these parameters align with the requirements, the production process achieves the desired product quality. The implementation employs Power BI and a simple database system, leading to waste reduction and improved material quality in the production process.

4.1.4.2.2. Digitalization in the Production Process

In transforming the production line, the company adopts Purdue Model, comprising five levels of industrial control system, as illustrated in Figure 4.8.

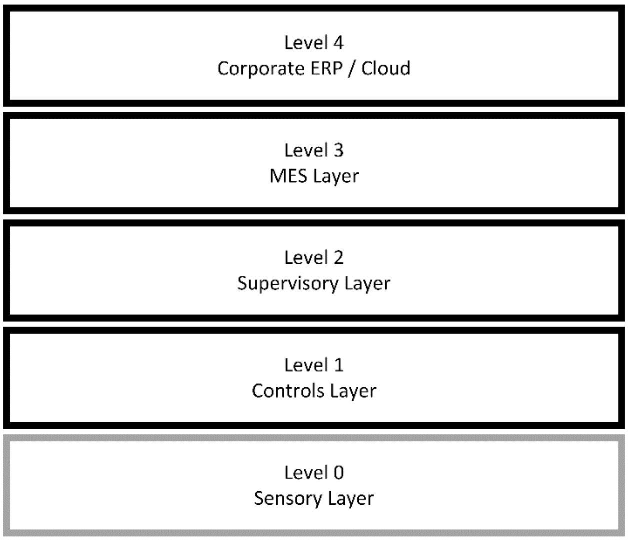

Figure 4.8: Purdue Model

1. Level 0 Sensory Layer consists of sensors and actuators in the system.

2. Level 1 Controls Layer involves PLCs controlling sensors and actuators on the machines. The company uses the latest version of PLCs capable of handling up to 12 machines simultaneously.
3. Level 2 Supervisory Layer enables humans to communicate with sensors and actuators by sending commands to PLCs via Human Machine Interface (HMI). The HMI provides process parameters and process flow diagram (PFD) of the whole process, allowing remote control of machines from the interface.
4. Level 3 Manufacturing Execution System (MES) acts as manufacturing management platform, displaying daily production plans, real-time machine status, and reasons for downtime. Personnels can input downtime reasons, allowing two-way communication. MES simplifies production management and enhances productivity. It eliminates manual data gathering for machine breakdowns, displaying the information on the HMI. Furthermore, production execution is now simplified by displaying production order and material readiness information on MES interface, eliminating SAP data extraction and the need for additional software.
5. Level 4 Corporate ERP serves as the backbone of the company, administering all the company's business functions. It includes corporate data lake, aggregating data from SAP and MES. This data enables analytics, generating insights and driving savings in utilities. The company collaborates with analytics vendor to leverage machine learning to derive insights from the data, eliminating manual data extraction and calculation, and improving reporting with PowerBI.

By following the model, digitalization in the company's production process has reached an almost touchless state, with only 2-4 persons per shift, particularly in fabric enhancer production line that covers an area equivalent to 60% of a soccer field. The system operates autonomously and is controlled by HMI. In addition, product formulas and their machine parameters can be configured and pushed automatically through this HMI, eliminating individual configuration on each machine.

In the case of shampoo production, the process is similar, with some manual handling processes due to its nature of the process, and each shift requires 6 employees for a smaller area compared to the fabric enhancer lines.

4.1.4.2.3. Digitalization in Warehouse

In addressing warehouse security, the company utilizes Excel and PowerBI to monitor and regulate the entry of suppliers' trucks into the plant area. The system gathers data, including trucks' position within the plant area, its ongoing process, license plate details, driver identities, the trucks' supplier, and the goods they are delivering. Prior to the initiative, truck monitoring was coordinated verbally. With this new system, the company gains visibility to identify trucks that exceed the maximum 24-hour limit within the plant area, reinforcing compliance with the company's security policy.

In the warehouse area, Autonomous Intelligent Vehicle (AIV) is employed which covers 20% of warehouse operations, reducing manual handling of heavy loads. AIV is a new generation of AGV which uses wireless technology for its routing. The warehouse management system (WMS) can efficiently assign nearby picking workers to pick required items and gather them at the collection point, optimizing workers' productivity. In addition, the company integrates its WMS with Transportation Management System (TMS) and distributors' ERP systems through a modified business intelligence dashboard. This dashboard enables the company's DC to receive notifications regarding potentially unfulfilled SKUs and displays the quantity of urgently required SKUs. Besides, the dashboard allows the warehouse team to monitor non-performing inventory (NPI) numbers, where a high count may indicate logistics issues.

To plan and optimize the daily delivery truck route, the company employs a specific TMS named Dynamic Routing System which is developed with third-party contractor collaboration. This system is developed using traveling salesman problem algorithm. This system relies on data, alert systems, dashboard, integrated API with distributors' ERPs and machine learning algorithms to reduce costs by determining the number of trucks required, whether provided by the company, distributors, or rental companies. The system uses volume filled rate (VFR) to assess truck loading efficiency, with the ideal threshold set above 80%. This ensures sustainable operations by reducing pollution and fuel costs while also preventing overloading, which can lead to longer delivery and loading times and increase maintenance costs.

4.1.4.2.4. Robotic Process Automation using Python

The production team in the company's plant utilizes Python to develop robotic process automation (RPA) algorithms. The RPA algorithms are employed to automate Goods Received and Goods Issue registration in SAP system. Prior to the implementation, the process involved manual checking and entering order numbers into the SAP system. After implementation, Python is used to extract data from Historian, the company's production operations database, enabling automatic verification of actual material consumption and input into the SAP system. This approach is interesting due to the company's strict application usage standards and effectively tackles the pain point of form filling.

4.1.4.3. Obstacles and The Efforts to Overcome

One of the challenges faced by the company is human behavior. In the case of TMS, there were adoption challenges in delivery personnels such as wrong clicks, and resistance to use the mobile application. Technical difficulties in implementing the TMS in the distributors and integrating it with their ERP system was another problem in implementing TMS. To address these problems, the company team conducted "hypercare" approach, involving a 2-week to 1-month period of close observation of the delivery personnels and distributors to refine the new solution and understand the actual process during the implementation. In addition, ongoing training is included within the "hypercare" period, involving time-motion study to the users. Meanwhile, implementation of Purdue Model in the production process requires leadership from operations team in the production to enforce and ensure a successful implementation.

Convincing distributors to adopt the company's digital solution and establishing objectives with them is another challenge. In the case of TMS, WMS and their integration with distributors' ERP systems, the company must effectively communicate and convince distributors that the new digital solutions offer more added value compared to the distributors' existing systems. This value extends beyond cost reduction, including benefits such as allowing distributors to reduce fixed costs in their transportation fleet. Accomplishing this involves engaging a multifunctional team, including finance, sales, logistics, IT, and HR, in discussions with the distributors to present a holistic view from each function's perspective. Following the proposal agreement with the distributors, both the company and the distributors establish targets and divide responsibilities for the solution development.

Another obstacle is securing funding from top management. As a multinational company, it possesses a corporate portfolio of applications utilized in its business operations and across its international plants. In the case of RPA using Python, the company has BluePrism in its portfolio which has higher cost. Despite of already in use at the company's European plants, implementing it in an Indonesian plant with lower labor costs would yield a lower return on investment. Therefore, the production team developed RPA algorithms using Python, which is free and contributes to employees' IT skills development.

In addition to the mentioned obstacles, inevitable geographic conditions of Indonesia are another challenge as the geographic is a vast dispersed archipelago with complex terrain and inadequate transportation infrastructures, entailing high transportation costs.

4.1.4.4. Enablers of Digitalization

As a part of a multinational company, compliance with the company's regulations and policies is crucial, particularly regarding IT governance. Every digital initiative, whether involving devices, applications, and software within the company's business processes, should undergo registration and assessment process. When creating an application, it requires registration with valid justification, considering the resources needed for application maintenance. Similarly, connecting sensor with LoRaWAN technology involves examination of the device, including its manufacturer, and specific WiFi technology requirements. Even for free software, it's necessary to check if the software is already registered within the company's system, including off-the-shelf software. For instance, the use of free Foxit PDF Reader was declined because the company already had Adobe PDF Reader subscription. This policy also extends to suppliers handling company data, involving confidential disclosure agreement (CDA), training, and infrastructure assessments. This compliance is critical to protect the company's values, emphasizing the parallel importance of value preservation alongside value creation.

Leadership is an inevitable requirement when implementing digitalization. Operations teams leverage their authority to enforce the adoption of digital solutions to their subordinates. In the case of maintaining digital legacy, leadership serves as the voice of reason. The digital team provides justification for using digital tools and connecting them with the daily tasks of operations team. For instance, a digital tool enables the operations team to eliminate manual work and meet their KPI of reducing manpower. This reduction doesn't entail employee layoffs but reallocates staff to other departments.

The company’s work method like Plan-Do-Check-Act (PDCA) cycle is another enabler of successful digitalization. Planning sets the stage for success by establishing project objectives, scope of work, and defining roles and responsibilities, which account for 70% of the work. Setting realistic targets is crucial to avoid overly ambitious goals which can lead to project failure.

4.1.4.5. Positive Impact of Digitalization on Supply Chain Sustainability

In the plant operations, the main objective of any improvement project, including digitalization, is to achieve cost savings, resulting immediate economic benefits. For instance, the company and distributors are actively promoting paperless operations by integration of TMS, WMS and distributors’ ERP systems. This initiative does not only address environmental concerns, but also reduces paper costs and minimizes data loss risks related to paper-based records. To illustrate, annual paper spending can amount to 4,000 – 6,000 Euros. Another example is implementation of analytics in utility area to drive savings through more efficient electricity usage, leading to reduced utility cost and waste.

Aside from paperless operations and reduced utility waste, the plant team has a KPI of maximizing material utilization for all purchased materials. The goal is to ensure 99% of material utilization, resulting in minimal waste generation. By employing process control strategy that improves production processes, materials are utilized more efficiently and effectively. Although the waste is minimal, it is collected and sold to a third-party vendor for treatment. Finally, reducing waste in production leads to a more sustainable process.

Through previously mentioned cost saving efforts, the team achieves capacity reduction. For instance, WMS implementation eliminates manual tasks, such as recording and reinserting data into the system, thanks to the digital. This leads to increased productivity as the team can handle more tasks due to job automation through WMS. Furthermore, capacity efficiency is not just about optimizing operations, but also optimizing capability, allowing one person to perform multiple tasks. Despite increased digitalization operations, there has been no effect on electricity consumption.

Besides capacity reduction, WMS implementation and integration with TMS and distributors' ERP systems offer real-time data updates. For example, inventory and NPI data are updated daily. Real-time data directly impacts processes utilizing the information, including better demand forecast due to better predicted orders. In addition, data regarding volume filled rate for delivery truck and store's order fulfillment percentage are now updated daily. Before these digital implementations, all mentioned data was updated on a weekly or biweekly basis.

Apart from mentioned advantages on business operations, digitalization also has social impacts on employees and the community. Employees have more free time due to digitalization, resulting in better well-being and fostering more ideas. During this spare time, they explore and discover innovative approaches to doing things, which are further supported by the company's digital team. Regarding the effect on the community, the company assists its raw materials suppliers implement PCS system and provide assistance to its distributors in managing and integrating their own ERP systems with the company's TMS and WMS. In conclusion, as a foreign-owned company, it transfers new capabilities to domestic companies.

4.1.4.6. Negative Impact of Digitalization on Supply Chain Sustainability

Implementation cost is one of the concerns in digitalization. There are two types of cost which are operational cost and one-time cost. Operational costs typically amount to 3,000 – 6,000 Euros annually, while one-time costs are substantially higher, ranging from 30,000 – 36,000 Euros. These high one-time costs are associated to the development, such as fine-tuning and the addition of temporary employees during the first three to four months. To mitigate these costs, the company conducts cost planning prior to the implementation, focusing on saving money during the initial three years of implementation.

Reduced human resources is also a key concern due to digitalization. In the case of WMS, WMS automates the job, reducing the need for human resources. To address the issue, the company adopts a policy of employing only permanent staff, eliminating seasonal hires during peak periods. In addition, the company uses a technician work system, emphasizing that all personnel possess versatile skills and can adapt to different departments.

There are several events of increased costs, NPI and bad environmental impacts due to initial adjustments in the integration between WMS and TMS within the distributors' ERP systems. For example, the first three months of integration caused a rise in delivery fleet size due to lack of data in the initial implementation, leading to higher fuel costs and pollution. Additionally, the initial implementation of forecasting system led to a 0.5 – 1% increase in NPI which had to be burnt according to government regulations, causing adverse environmental effects.

4.1.4.7. Internal Contingencies of Digitalization on Supply Chain Sustainability

Being a multinational corporation, the company employs top-down approach management to prioritize projects, starting at regional office and cascading down to the Indonesia office. Furthermore, the company's top management conducts annual meetings to prioritize digital implementation projects, including evaluations of projects and defining strategies and vision for the upcoming year with specific targets for each business unit.

Besides a top-down management approach, the company fosters a knowledge sharing culture. The Indonesia office is part of Asia, Middle East, Africa (AMA) region within the company, which conducts sharing sessions among countries in the region. These sessions facilitate sharing of problem-solving approaches, allowing each country's plant to inspire and support one another when facing similar problems. Furthermore, the company incentivizes employees to explore and learn by giving reward and recognition for those who create innovative ideas, not limited to digital solutions. There are also awards dedicated to digital innovations. Moreover, ideas from soft floor workers also drive digital implementation. Daily stand-up meetings allow employees to identify operational issues and encourage brainstorming for solutions. Thus, the company combines a top-down management approach, culture of innovation and bottom-up problem-solving initiatives.

4.1.4.8. External Contingencies of Digitalization on Supply Chain Sustainability

External factors influence the company in the company's digitalization efforts within its supply chain and sustainability strategy. Top management actively explores innovative external solutions and cascades these insights down to the lower company levels.

Competitors act as a motivating factor for continuous improvement, although the influence affects sales rather than the supply chain. This is due to company's unique supply chain strategy, with fewer than 10 distributors across Indonesia, in contrast to the competitors which have over 20 distributors. This distribution condition impacts the delivery time of the company which can take 2 days for distribution in Java while the competitors can serve one-day delivery time.

Business partners, including distributors and raw materials suppliers, play roles in the company's digitalization journey. The company conducts monthly evaluations with the distributors to ensure successful partnership with no loss in their operations. One of the evaluations was about the integration of TMS, WMS and their distributors' ERP systems. Moreover, the company assists raw material suppliers to implement PCS in their production process.

In terms of government support for digitalization, it remains limited. Meanwhile, the regulatory influence is significant. A case involving a government ban on cough syrup drug sales due to alleged cause of kidney failure impacts the company. This prevented product sales for two months, resulting in higher NPI in the warehouse. The company followed BPOM regulations in addressing this issue and had to destroy some products due to compliance with expiration dates.

Customer feedback indirectly affects the company's digitalization journey, including complaints about product defects and the need for faster deliveries.

4.1.4.9. Future Focus on Digitalization

In the production area, there are two key projects. The first involves implementing digital twin to double machine capacity, simulating the real condition of the expansion. The increased capacity impacts to increase machine productivity, allowing the Indonesian plant to sell the machine to other company plants. Fewer machines mean reduced operational costs and depreciation. The second project focuses on achieving 100% digital control of product samples to give quality assurance to the company's DC. In the current system, the plant needs to provide assurance money as a guarantee for product quality, based on checked product samples. By implementing 100% digital sample checking, the plant can eliminate the need to pay assurance money to the DC. The parameter checked in the process is the filled weight, ensuring the actual injected volume of product content. Besides the mentioned projects, the company is also driving savings in the utility area.

In the human resource area, the company creates upskilling program for the employees and integrate it as a part of employee promotion and career development. This includes obligations to complete various digital skills for career advancement.

In the distribution area, the company is required to upgrade its supply network design, which occurs every five years. These changes require fine-tuning and adjustment of current digital solutions, such as cost calculation automation, leveraging the availability of current data. The impact of these upgrades affects capacity improvements, reducing costs and people's capacity.

4.2. Cross-Case Study Analysis

Table 4.1: A summary of with-in case analysis.

	Ice Cream Company	Powdered Beverage Company	Instant Noodle Company	Personal & Fabric Care Company
Technologies	1. Web-based applications 2. PowerBI dashboards 3. Programmable Logic Controller 4. Remote control of ice cream cooler	1. Supplier's documents submission web platform 2. Integration between ERP system, WMS, and other applications 3. Manufacturing Execution System 4. Robotic Processing Automation	1. Truck Queueing System (TQS) 2. E-Purchasing Monitoring (EPM) 3. Integration between ERP system, TQS, and EPM 4. Auto-recording and digital approval in ERP system 5. Automatic daily report	1. Supplier's documents submission web platform 2. Process Control Strategy in raw material suppliers 3. Industrial control system using Purdue Model 4. Excel and PowerBI for truck monitoring 5. Autonomous Intelligent Vehicle (AIV) 6. Warehouse Management System (WMS) 7. Dynamic Routing System (DRS) 8. Integration of WMS, DRS, and distributors' ERP systems 9. Robotic Processing Automation using Python
Internal Contingencies	1. Global headquarters directives 2. Internal collaboration between the company's plants 3. Infrastructure readiness	**1.** Top management **2.** Strategic plans with specific objectives 3. Innovation as work culture	1. Top management 2. Careful annual plan 3. Sequential project approval process	1. Regional headquarter and top management 2. Culture of knowledge sharing and innovation 3. Rewards and recognition to incentivize employees 4. Ideas from soft floor workers
External Contingencies	1. Competitors 2. Regulatory bodies	1. External technology development 2. Government 3. Customer shopping habit 4. Foreign agency entity	1. External vendors 2. Technological fairs	1. Innovative external solutions 2. Competitors 3. Business partners, including distributors and raw material suppliers 4. Regulatory bodies 5. Customer feedback

Positive Impacts of Digitalization on Sustainability	1. Eliminate non-value-added activities 2. Reduce overtime budget 3. Reduce lost spare part and enable the spare part usage tracking 4. Remote monitoring 5. Prolong lifespan of documentation 6. Simplify investigations in case of issues 7. Encourage employees to make improvements 8. Ease identification of production workstation to be improved 9. Reduce electricity consumption	1. Have access to more valid and real time data 2. Improve productivity 3. Reduce costs 4. Encourage eagerness of employees to learn about technologies 5. Reduce paper usage **6.** Reduce pollution and fuel costs	1. Enable remote and real-time monitoring 2. Enhance the process evaluation for faster decision making 3. Ease identification of areas to be improved 4. Ease process improvement, resulting in better efficiency, reduced waste, and increased production outputs 5. Minimize human error 6. Securely store data on the server 7. Embrace paperless operations 8. Improve productivity 9. Simplify data analysis and processing 10. Enhance communication among departments 11. Encourage young employees to contribute to company's digitalization	1. Reduce costs 2. Reduce paper costs and minimize data loss risks related to paper-based records 3. Have more efficient electricity usage, leading to reduced utility cost and waste. 4. Reduce waste and improve material utilization 5. Eliminate manual tasks 6. Have access to more valid and real time data 7. Reduce pollution and fuel costs 8. Have better well-being for employees and fostering more ideas 9. Transfer new capabilities to domestic companies
Negative Impacts of Digitalization on Sustainability	1. Increased waste and overconsumption during first installation of new machines 2. Substantial upfront investment for digitalization	1. High cost of development 2. Reduce manpower 3. Reduce critical thinking 4. Temporary decrease in production output due to transitional stage	1. Initial high investment cost 2. Reduce employment	1. High implementation cost 2. Reduce human resources 3. Generate NPI and bad environmental impacts due to initial adjustments of integration between WMS, DRS, and distributors' ERP systems

The findings from the four case studies in the with-in case analysis are summarized in Table 4.1. Below are discussions regarding comparison of technologies, positive and negative impacts of digitalization on sustainability, internal and external contingencies between four companies.

4.2.1. Technologies

During with-in case analyses, it is evident that the case companies employ the same technology to achieve the same purpose. For instance, three out of four companies focus on system integration, such as integration between ERP and other applications along the supply chain. Besides, web-based platforms are utilized by these companies to replace paper-based processes and connect with the raw material suppliers. This was said by OAM from the ice cream company when explaining EWO, stating,

> "Previously, it was done by paper. Many records were not properly archived. Now, we utilize web-based application which is paperless."

These companies are also progressing in digitizing their production process in their own way, enabling direct data extraction from the machine. In addition to data extraction, the digitalization of production process enables more controlled electric consumption through PLC usage, as seen in the operations of ice cream company and personal and fabric care company. Moreover, job automation, including robotic process automation (RPA) and automatic daily report are also employed, eliminating manual tasks. BAM from the powdered beverage company mentioned this when explaining RPA, describing,

> "… RPA is quite clear. The purpose is to eliminate repetitive processes that were traditionally performed by human, although it can be automated by system."

Additionally, PowerBI dashboards are used by ice cream company and personal and fabric care company for monitoring tasks. This was shared by OAM from the ice cream company when explaining the PowerBI implementation, elaborating,

> "PowerBI is employed to display. Its function is to identify areas with the most breakdowns or the highest waste. This allows us to identify the specific location."

Apart from the shared technology, there are specific technologies the case companies used in their operations. Remote control technology is used to control cooler in ice cream company, although it is currently inactive for security reasons. TQS and EPM are self-developed applications by the instant noodle company to assist company's operations related to truck and purchasing management. On the other hand, personal and fabric care company employs Process Control Strategy to ensure raw material quality, AIV for warehouse operations, and DRS to optimize truck delivery routes.

4.2.2. Positive Effects of Digitalization on Sustainability

Digitalization brings consistent benefits to the case companies across various dimensions. Environmental improvements include reduction in waste, electricity consumption and paper usage. In the operations, it lowers cost and eliminates manual and non-value-added activities, leading to increased productivity and minimized human errors. As stated by OAM,

> "Digitalization improves non-value-added activities previously done manually. These tasks now can be tracked in real time. Operators can do other tasks or can be trained to process the data and design Kaizen or other tasks. So, this shifts them towards more valuable works."

Furthermore, access to more valid and real-time and integrated data enables faster decision-making, minimizes human errors, eases identification of areas to be improved, streamlines data analysis and processing, and enhances communication between departments. These benefits are underscored by SDS from the instant noodle company, stating,

> "Digitalization simplifies everything, such as easier analysis process. Decision making can be made faster. In addition, due to the automation, errors are minimized, reducing human errors."

In addition, the digital system prolongs the document lifespan, simplifies issue investigations, and minimizes data loss risks related to paper-based records because the data is currently stored in the server. OAM mentioned these specific benefits in relation to the EWO and PTW application, as he explained,

> "Digitalizing EWO increases archival lifespan, In the case of major accident, we can trace from one platform. Additionally, servers can store data for longer periods compared to paper-based methods which need to be check individually. The electronic PTW can be accessed simultaneously by everyone, simplifying investigation. The same thing applies to the EWO; in case of machine breakdown, we can trace the breakdown history, checking for connection between past and current trend of breakdown. Therefore, this expedites the analysis and investigation in the event of major incident."

In the social context, digitalization improves employees' well-being due to job automation and encourages all companies' employees to contribute improvement ideas, learn about technologies to support ongoing digitalization efforts. This was highlighted by ITP from the personal and fabric care company, explaining,

> "Employee well-being has been an interesting indicator in the past year because everyone is coming up with more ideas. When someone generates more ideas, it means they have more free time. During their free time, they explore and discover new things. Each time someone uncovers something new, the digital team is there to facilitate."

There are also specific advantages experienced by companies due to digitalization. The ice cream company can reduce lost spare parts and track the spare part usage through CMMS. The powdered beverage company and the personal and fabric care company cut pollution and fuel costs by employing the best route algorithm for delivery truck routes. The ice cream company and instant noodle company can remotely control the cooler, and monitor truck movements in TQS, respectively. Additionally, the personal and fabric care company's assistance to its raw material suppliers in implementing process control strategy transfers new capabilities to these mostly domestic suppliers.

4.2.3. Negative Effects of Digitalization on Sustainability

Besides its benefits, digitalization presents certain drawbacks for the case companies. High implementation cost is identified as the economic concern of the digitalization across all case companies. PRM from the powdered beverage company emphasized this concern by stating, "Developing digitalization is indeed costly. There are numerous factors that can lead to digitalization failure. When we implement the digitalization without aligning it with the requirements, lacking mindset to change, and without ensuring the robustness of the hardware, we end up wasting money."

To anticipate it, they ensure that the proposed applications align with their requirements and conduct thorough cost and benefit analyses before the implementation. BFM from the instant noodle company underlined this approach, saying,

"… . If digitalization is treated as an investment, investments are naturally costly. However, it can be anticipated by calculating the economic parameters like the payback period and capital. Every project always involves economic considerations."

Reduced employment is another shared concern, which has social implications. To mitigate this, the companies reallocate and transfer the affected employees to other departments. BAM from the powdered beverage company discussed this issue when addressing the drawbacks of digitalization, stating,

"… . There were some layoffs, but not many. Some contract extensions were also cancelled. … . To anticipate this, for example, we prepare the affected employees for other roles, or we upgrade their skills, so they can collaborate with the robots (in this case, RPA)."

Additionally, the powdered beverage dedicates work processes that only employ non-permanent workers. This was addressed by PRM, saying,

"Reduced employment due to digitalization is inevitable. … . However, the company has anticipated it by reserving certain positions for non-permanent employees. The goal is when digitalization occurs, there is no need to cut permanent employees."

Furthermore, each company has experienced specific disadvantages. The ice cream company and personal and fabric care company experienced increased waste and overconsumption during initial adjustment of their digital solutions. ITD from the personal and fabric care company mentioned this challenge when implementing the integration of WMS, DRS, and distributors' ERP systems, stating,

"In the first three months, we already expect that there will be an increment of fleet and NPI. We already expect that and had planned for it. The issue of these 3 months should be corrected in the next three months. … . By the fourth to sixth month (after implementation), there should be savings from the increment (of the fleet and NPI). …"

On the other hand, the powdered beverage company experiences reduced critical thinking due to overreliance on the technology and temporary decrease in production output due to transitional stage to new digital system.

4.2.4. Internal Contingencies

All case companies acknowledge that top management holds a crucial role in directing their digitalization journey through a top-down management approach. Multinational companies, such as ice cream company and personal and fabric care company enforce this approach by setting global projects for their worldwide plants. This mentioned by OAM when discussed about EWO implementation, explaining, "Previously, operators were not disciplined to submit EWO papers. I was told a story by someone that … EWO papers just stacked without any advanced analysis. Then, he/she saw those piles of papers were thrown away, decreasing operators' engagement to raise work request with EWO. So then, there was a loss of analysis. When global HQ people needed to review loss breakdown history, we did not have the data. This prompted the global HQ to push for detailed analysis in CAPEX or improvement proposals. From that event, we began and changed the culture by digitizing (the EWO paper). We installed tablets on each machine. … . The HQ personnel pushed the (plant) management to implement (the project)."

Additionally, the personal and fabric care company emphasizes compliance with corporate regulations and policies regarding IT governance. Meanwhile, vertically integrated local company, like the instant noodle company ensures alignment with the parent company's vision by conducting discussions on all digitalization initiatives. BFM mentioned this by stating,

"Every program within the unit must align with the viewpoints and perspectives of the Head Office. … . So, before the project starts, we already discussed every possibility …, objectives, making the concept relatively the same (between Head Office and unit)."

In the case of a single company like the powdered beverage company, the CEO encourages the middle management to use digital tools in their business processes. In addition to top management directives, leadership from each supply chain process leader plays a vital role in ensuring successful digitalization execution and consistent operations.

The work culture of the companies also impacts their digitalization efforts. For instance, collaboration between plants in the ice cream company and the personal and fabric care company facilitates problem solving through knowledge sharing sessions. ITD from the personal and fabric care company highlighted this approach, saying,

"There are two main factors that drive (digitalization), which are … customer insight …. and internal insight. Internal insight means, for example, there is internal learning session from Saudi or Australian plant related to supply chain interventions that have proven effective. After we reflect, we realize that similar problems exist in our Indonesian plant. We learn and reapply the method used by the foreign plant. Typically, we first identify the issues in our plant and consider customer insight before making decisions. If there is a solution from regional team, we implement it accordingly, otherwise, we develop our own solution."

The culture of innovation also fosters the companies' employees to generate improvement ideas. To sustain innovation culture, the case companies have their own methods, including giving rewards and recognition and holding daily stand-up meetings, as done by the personal and fabric care company, and organizing innovation showcase event, as seen in the powdered beverage company.

Developing strategies with specific objectives holds a significant role in digitalization journey of the case companies. This includes aligning technology solutions with requirements and problems, conducting cost-benefit analyses, communicating with the affected departments, and establishing clear SOPs related to digitalization. In the instant noodle company case, sequential project approval process is also applied to ensure a controlled process during implementation.

Furthermore, ensuring readiness of required resources for digitalization is vital, encompassing both infrastructure and human resources. The infrastructure focuses on ensuring the system's robustness and its hardware components. Simultaneously, human resources should be equipped with necessary skills and mindset through comprehensive training in babysitting period. In the previous context, the powdered beverage company also enhances employees' digital skills through digital awareness training.

4.2.5. External Contingencies

Development of technologies outside the case companies are one of the external factors that influence the case companies' digitalization efforts. To keep updated, the companies actively follow the development by attending technological fairs, and inviting technology vendors to explain about potential technologies that can be implemented in their processes, as demonstrated in the instant noodle company case. This was mentioned by BFM during the discussion of external contingencies, stating,

> "Sometimes, we deliberately invite several automation vendors. They share their experiences, and we try to relate these experiences to our business. These vendors' experiences serve as our references in improvement initiatives. …"

Benchmarking competitors despite the limited data also helps them update about technology trends in ice cream company and personal and fabric care company.

Regulatory bodies, like BPOM and Bureau Veritas, indirectly encourage document digitization, as seen in the ice cream company case. OAM highlighted this factor by elaborating,

> "During BPOM audit, it asked for many documents. Actually, it (refers to driving factor) does not originate externally, but internally. During the audit, we encountered difficulty in compiling documents and other information. So, we took initiative to centralize all required files into a single platform, like Sharepoint or other applications, such as EWO or CMMS, particularly when BPOM requested information related to freezer maintenance, etc."

In addition, cooperation between government and international development agencies promotes digitalization through training and consultancy sessions, particularly in the powdered company case. FDT shared on GIZ's support through email with the author, stating,

> "Firstly, the powdered beverage company can access GIZ's support in the form of training through networking. … . As far as I know, GIZ funds originate from the German government, not the Indonesian government. Indonesian government primarily provides guidance, grants access to industries in Indonesia and supervises the programs. …, this GIZ program primarily empowers from people or human resources aspect, while the Ministry of Industry focuses on comprehensive 'Industry Digitalization' covering aspects of people, process, and technology side."

Business partners, including distributors and raw material suppliers contribute to the company's digitalization journey. The personal and fabric care company assists its suppliers in implementing process control strategy, enhancing the raw materials' quality, and subsequently affecting production quality. ITP explained this collaboration during the interview, stating,

> "… . We worked starting from the supplier side. We assisted them in applying PCS through simple tools, such as PowerBI and basic database to manage process control strategy, benefiting both us and our suppliers by reducing waste. Consequently, it results in better raw material quality. …"

They also encourage distributors to integrate their ERP systems with the company's system. Similarly, the instant noodle company encourages non-group transportation vendors to install GPS for tracking truck movements during deliveries.

Moreover, customers play an important role in influencing digitalization initiatives. In the powdered beverage company, shifting customer habit towards online shopping drives the company to tap into the e-commerce markets. Meanwhile, customer feedback, including product defects complaints and the demand for faster deliveries, indirectly influences the personal and fabric care company to improve their business processes.

5 Discussion

5.1. Reflection on Findings against Reviewed Literature

The case analyses have uncovered various key findings. To understand how these findings align or contrast with the reviewed literature, the following discussions cover technologies, positive and negative impacts of digitalization on sustainability, internal and external contingencies.

5.1.1. Technologies

In some cases, the case companies utilize technologies discussed in the reviewed literature. For example, all case companies employ ERP system as the backbone of their business operations, alongside warehouse management systems for inventory management. In addition, the ice cream company, and the personal and fabric care company harness business intelligence tools like PowerBI for monitoring purposes.

Furthermore, there are technologies mentioned in the reviewed literature that are employed by the case companies, but with different terminology and specific purposes. For instance, IoT technology is utilized for auto-recording in the instant noodle company, while it is integrated into the manufacturing execution systems with PLCs in the powdered beverage company and the personal and fabric care company and. Artificial intelligence and machine learning are also applied in the delivery truck routing system of the personal and fabric care company and the powdered beverage company.

Beyond the technologies found in literature, there are several technologies not mentioned in the literature. For instance, they integrate ERP systems with other supply chain applications to enable data integration between applications and eliminate manual tasks. The personal and fabric care company utilizes AIV in their warehouse operations using wireless technology for its routing. Web-based applications are adopted in all cases to replace paper-based processes and facilitate order coordination with suppliers. Another example is robotic process automation which is harnessed by the powdered beverage company and the personal and fabric care company to automate repetitive tasks. The remaining specific technologies in each company can be found in the technologies section of Table 4.1 and are developed in-house.

It is important to highlight that, before selecting a technology to be implemented, the case companies emphasize conducting cost-benefit analysis and ensuring the alignment between the technology and the specific problem to be addressed. Cheap labor in Indonesia is one of the considerations mentioned by the personal and fabric care company while deciding to use Python instead of BluePrism in RPA implementation. Therefore, cutting-edge technologies with high cost like blockchain are not currently being considered for digitalization.

5.1.2. Positive Impacts of Digitalization on Sustainability

In general, the benefits experienced by the case companies are in accordance with the reviewed literature. To relate case study findings with the existing framework of reviewed literature presented in Figure 2.7., the discussion is conducted individually for each case company.

5.1.2.1. Ice Cream Company

The ice cream company adopts various digital tools to enhance its operations. Web-based applications such as E-PTW, EWO, and CMMS have replaced paper-based processes, leading to reduced paper waste, reduced overtime budget through E-PTW application, enhanced transparency in tracking spare part usage, and increased process efficiency by simplifying issue investigations and eliminating non-value-added tasks. PowerBI dashboards have improved employment conditions by encouraging innovation and increased process efficiency by identifying areas to be improved and simplifying data extraction and processing. The use of PLC in machinery control increases resource usage efficiency by reducing electricity consumption. Moreover, remote control of ice cream cooler enables real-time monitoring of operations.

5.1.2.2. Powdered Beverage Company

Digitalization of the powdered beverage company has benefited its business processes. The tender submission platform centralizes the procurement management, while weighing application eliminates human error in manual weighing. Integration between WMS and related applications streamlines business processes, while manufacturing execution system (MES) integrates and streamlines the manufacturing processes. RPA eliminates manual and repetitive tasks. In summary, previously mentioned digital improvements offer increased process efficiency.

Integration between systems and applications also provides access to more valid and real-time data and reduces paper waste and cuts cost which is aligned with findings from Oubrahim et al. (2023). Moreover, MES has increased process transparency and real-time data access as data is directly extracted from machines. These effects of MES are aligned with studies from Ding (2018) and Nayal et al. (2022). Besides, RPA improves employment conditions by eliminating repetitive tasks and increasing productivity. These digital innovations enhanced employment development by encouraging employees to learn about technology.

5.1.2.3. Instant Noodle Company

The instant noodle company has harnessed several digital tools in its business processes. TQS allows remote and real-time monitoring of delivery truck movements. The EPM system increases process efficiency by centralizing the procurement management for non-group vendors. Auto-recording and digital approval of the SAP ERP system reduce paper waste, enable real-time data access, and increase process efficiency by eliminating human error of previous manual paper recording. Integration between ERP, TQS, and EPM increases process efficiency and enables real-time data operations, improving communication between departments that is aligned with study of Ding (2018). Automatic daily reports also improve process efficiency and employment condition by eliminating repetitive data processing tasks and enhancing meeting effectiveness. Additionally, all mentioned digital implementations encourage young employees to contribute to company's digitalization efforts which improve employment development.

5.1.2.4. Personal and Fabric Care Company

The personal and fabric care company has executed several digital improvements in its processes. The material certification upload platform for suppliers increases process efficiency by eliminating individual certificate checks. Assisting suppliers in implementing Process Control Strategy increases resources usage efficiency, yielding to better production output, and empowering the community, particularly domestic suppliers. MES implementation in the production line reduces paper waste and increases process efficiency by streamlining the production data from machines and simplifying data extraction and processing. The usage of PowerBI and Excel in truck monitoring enables compliance with the plant's security policy. The use of AIV in the warehouse improves employment conditions by reducing manual handling, while the WMS enhances process efficiency by efficiently assigning nearby picking workers. The Dynamic Routing System (DRS) increases process efficiency, reduces pollution, and cuts costs by optimizing daily delivery routes and ensuring sustainable operations to prevent higher maintenance costs. Effects of DRS are in line with the research of Kunkel et al. (2022). The integration between WMS, DRS and distributors' ERPs improves process efficiency by streamlining processes and enabling real-time operations. Python-based RPA has increased process efficiency by removing manual checks and data entry, while also contributing to employment development by honing employees' programming skills. These digital improvements have collectively improved employees' well-being and foster them to create more ideas which align with studies from I. S. Khan et al. (2021) and Oubrahim et al. (2023).

5.1.2.5. New Positive Impacts

Beyond the mentioned benefits that align with the existing framework, new positive impacts have been uncovered. Prolonging lifespan of documentation and reducing data loss risks due to transition from paper-based processes to digital data storage, are notable findings from the case studies.

5.1.3. Negative Impacts of Digitalization on Sustainability

Drawbacks that are encountered by the case companies due to digitalization are largely aligned with the reviewed literature. All case companies admitted that digitalization entails high implementation cost which is align with findings of Nantee & Sureeyatanapas (2021). To address this, the companies align the digital tools with specific problems and examine the technologies' cost and benefit beforehand.

Unavoidable overconsumption and increased waste also occurred during initial digital tool adoptions in the ice cream company and the personal and fabric care company. Unlike the findings of Nantee & Sureeyatanapas (2021), rising electricity consumption did not apply in the case companies, except for the powdered beverage company. However, the economic benefit still outweighs the associated electricity costs.

Reduced employment is another consequence due to automation, such as RPA in the powdered beverage company and WMS in the personal and fabric care company which eliminate repetitive works and replace human role. To address this, the companies transfer affected employees to other departments, and apply strategies, such as dedicating certain processes to non-permanent workers in the powdered beverage company. However, information exposure issues did not appear in the case companies.

Beyond the mentioned drawbacks in the reviewed literature, the powdered beverage company faced two additional issues which are reduced critical thinking and an inevitable temporary decrease in production output due to transitional stage. To address the issues, the company holds an annual innovation showcase event to trigger employees' improvement ideas.

5.1.4. Internal Contingencies

The internal factors influencing digital implementation within the case companies are mostly in line with the reviewed literature. The top management plays the central role in shaping the digitalization journey. This encompasses vision, pre-implementation analysis and implementation strategies which are in line with findings from Chaouni Benabdellah et al. (2023) and Torres da Rocha et al. (2022). The pre-implementation analysis focuses on aligning the technology with the specific problems and conducting cost-benefit analyses to address the high implementation costs. The implementation strategies involve annual planning and setting clear objectives. For example, the personal and fabric care company uses rewards and recognition to incentivize the employees to generate digital improvement ideas, while the instant noodle company follows sequential project approval processes. In addition, leadership of section leaders along the supply chain is vital to ensure the proper execution of digitalization, as emphasized by all case companies. Overall, top management holds pivotal role in securing the economic sustainability of the company due to digitalization by checking the alignment between digital solutions and problems, conducting cost-benefit analysis, annual planning, and ensuring proper execution through effective leadership of each supply chain section leader.

Furthermore, work culture is also influencing the digitalization journey of the case companies, including collaboration and innovation. Collaboration applies both internally and externally. Sharing sessions between worldwide plants in the ice cream company and the personal and fabric care company is an example of internal collaboration, enabling plants to support and inspire each other in their digitalization efforts, in line with findings of Benzidia et al. (2021). Meanwhile, external collaboration extends beyond company boundaries. For instance, the personal and fabric care company's assistance to raw material suppliers regarding process control strategy implementation and integration with distributors' ERP systems are aligned with findings from Bag et al. (2020), Tseng et al. (2022), and Oubrahim et al. (2023). Another example is assistance from Ministry of Industry and GIZ in the powdered beverage company's digitalization journey, aligning with findings of Niehoff et al. (2022). In terms of fostering innovation, daily stand-up meetings in the personal and fabric care company and annual innovation showcase event in the powdered beverage company are examples of how companies encourage their employees to generate improvement ideas. In summary, work culture like collaboration and innovation indirectly contributes to employees' skill development, positively influencing employment conditions. Specifically, in the case of personal and fabric care company, collaboration benefits the community, especially raw material suppliers, by transferring new capabilities that improve their process efficiency and reduce waste.

It is important to prepare readiness of both human resources and infrastructure for digital implementation. Digital awareness training in the powdered beverage company and having standby developers during babysitting period of digital implementation among the case companies are examples of efforts to mitigate employees' reluctance during the implementation, in line with insights of Hassoun et al. (2022). Aligning digital solutions with specific problems and assessing system's robustness and its hardware components are unavoidable efforts to ensure infrastructure readiness, consistent with findings of Jayashree et al. (2022).

Although the reviewed literature highlights the importance of data reliability, the case companies did not explicitly mention it as direct internal factor in their digitalization journey. Reliable and real-time data enables them to identify areas to be improved and expedite decision making, in line with the observations of Seddigh et al. (2022) and Chaouni Benabdellah et al. (2023).

It is worth noting that there is an implicit prioritization of sustainability within the digitalization journey, particularly in addressing negative impacts. The case companies demonstrate this by ensuring the alignment between technology with specific problems and conducting cost-benefit analyses to assess economic feasibility before the implementation. To mitigate direct negative impacts to employees, they transfer affected employees to other departments and establish policies, such as dedicating certain work processes exclusively for non-permanent employees in the powdered beverage company. However, there is no specific strategy from the case companies to address the negative impact to the environment, notably the inevitable increased waste during initial digital implementation in the ice cream company and the personal and fabric care company. The powdered beverage company also considers environmental benefits as a spillover effect rather than the primary focus of their digitalization efforts. In summary, the companies prioritize economic aspects before the implementation, followed by addressing the impacts on employees, and finally considering the environmental effects, particularly in dealing with negative impacts on each sustainability aspect.

5.1.5. External Contingencies

External factors affecting the case companies correspond with the reviewed literature and reveal new insights. Government involvement is illustrated in the powdered beverage company case, providing training and consultancy in cooperation with GIZ. This corresponds with research of Zhong et al. (2017) and Kunkel et al. (2022). Moreover, the Indonesian government offers fiscal incentives such as deductible tax, tax allowances and tax holidays to companies partnering with vocational school and establishing R&D centers (Ministry of Industry Republic of Indonesia, 2019), as documented in prior studies (Beier et al., 2022; Bressanelli et al., 2021; Dongfang et al., 2022; Yu, Khan, et al., 2022). It is important to note that proactively maintaining network with other industry stakeholders, such as Ministry of Industry and technology providers is essential to access the government support, as observed in the powdered beverage company case. Hence, government support not only contributes to companies' economic sustainability through fiscal incentives, but also nurtures skill development of the employees through training and consultancy.

Customers also play a role in digitalization journey of the case companies. However, there is no direct pressure on the case companies to adopt digital tools or environmentally friendly initiatives, which differs from findings of Gupta & Singh (2021) and S. A. R. Khan et al. (2022). In the case companies, customers indirectly influence digitalization journey, including product defect complaints in the personal and fabric care company and shift to online shopping habits in the powdered beverage company.

Beyond the mentioned external factors, the case study research unveils novel insights. Business partners, including raw material suppliers, distributors, and technology vendors contribute to the company's digitalization journey. For instance, the personal and fabric care company assisted its suppliers in implementing process control strategy, improving the raw materials' quality which yields better production quality. They also urge distributors to integrate their ERP systems with the company's system. Similarly, the instant noodle company pushes non-group transportation vendors to adopt GPS for tracking truck movements during deliveries. Furthermore, technology vendors contribute by keeping the case companies updated about technology developments, as demonstrated in the case of instant noodle company and powdered beverage company. To wrap it up, business partners have mutual beneficial relationships with the company. They keep the companies updated with current technology through the technology vendors, indirectly developing employees' knowledge. On the other hand, companies transfer new capabilities to local companies, as demonstrated in the personal and fabric care company case.

The study also reveals that regulatory bodies like BPOM and Bureau Veritas indirectly promote document digitization, as shown in the ice cream company case. International development agencies such as GIZ support the digitalization journey by collaborating with the government and assisting the digital training, as exemplified in the powdered beverage company case. Lastly, benchmarking competitors despite the limited data availability helps them stay updated about technology trends, as evidenced in ice cream company and personal and fabric care company.

5.2. Framework Refinement & Enrichment

Upon reviewing the case study findings alongside the existing literature, several new insights have emerged. These findings will be incorporated into the current framework of Figure 2.7.

5.2.1. Positive Impacts of Digitalization on Sustainability

The case studies largely confirm the positive impacts outlined in the existing framework. Nonetheless, the case studies unveil new benefits related to data management. As digitalization replaces paper-based process, data is now securely stored on servers. This transformation leads to two key advantages which are longer documentation lifespan and reduced data loss risk associated with paper records. Consequently, both advantages can be categorized as "Extend document lifespan and reduce data loss risk".

5.2.2. Negative Impacts of Digitalization on Sustainability

The negative impacts in the existing framework mostly correspond with the case studies, except information exposure which did not occur in the case companies. There are also new findings specific to the powdered beverage company, which include temporary decrease in production output due to transitional stage and reduced critical thinking attributed to a potential over reliance on technology. Since reduced critical thinking is associated with employment conditions, it makes sense to merge this drawback with "Reduce Employment", renaming the category as "Reduce Employment Condition". Meanwhile, the decrease in production output can be disregarded as it is a temporary consequence of the transitional stage.

5.2.3. Internal Contingencies

The case studies validate the internal contingencies outlined in the existing framework while introducing new insights. Notably, top management within the case companies not only defines the vision on digitalization, but also formulates the implementation strategy. Consequently, "Management Vision" and "Implementation Strategy" are merged to be "Top Management" to encompass both factors, which can vary based on the company's structure, whether multinational, vertically integrated or standalone.

Furthermore, the case studies reveal that collaboration and integration are integral part of the work culture of these companies. Alongside these, there is culture of innovation, demonstrated by annual innovation showcase event in the powdered beverage company and daily stand-up meeting in the personal and fabric care company. To encompass these work cultures and other specific work culture practices, "Collaboration & Integration" is reframed as "Work Culture".

When it comes to human capital and infrastructure readiness, they go together, as both are essential for successful digitalization. For instance, in the case of the ice cream company, the installation of tablets in production machines is complemented with user training. Similarly, both personal and fabric care company and powdered beverage company employ a "babysitting" period during digital tool implementation, allowing prompt issue resolution, and immediate user feedback. Given this interdependence, both factors are unified under "Resource (Human & Infrastructure) Readiness" since they must progress simultaneously.

5.2.4. External Contingencies

The case studies affirm the external contingencies outlined in the existing framework while presenting new insights. Both government and customers influence the digitalization journey of the case companies. In the case of the powdered beverage company, the Indonesian government through the Ministry of Industry and the Ministry of National Development Planning provides guidance through training and consultancy, while also establishes fiscal policies to encourage the digitalization of industries and companies. On the other hand, customers indirectly influence the digitalization journey through their adoption to online shopping habits in the case studies.

Additionally, the case studies reveal that business partners, encompassing raw material suppliers, distributors, and technology vendors, are involved in digitalization journey. This involvement is evident in the case of the personal and fabric care company and the instant noodle company, where they encourage and assist their raw material suppliers and distributors to implement digital tools. In addition, technology vendors keep the company updated with current technology developments, as illustrated in the case of instant noodle company and powdered beverage company. These examples can be collectively categorized as "Business Partners".

The study also unveils the influence of regulatory bodies, as evidenced in the ice cream company case. Furthermore, international development agencies contribute to the digitalization journey, as seen in the powdered beverage company case. Moreover, competitors serve as benchmarks for companies despite the limited data available. Given the distinctive roles between these three parties, they can be categorized as separate external factors: "Regulatory Bodies", "International Agencies", and "Competitors".

5.3. Final Framework

After incorporating the new insights from the case studies into the existing framework of Figure 2.7, the final framework is depicted in Figure 5.1. This proposed framework can serve as a reference for companies embarking on digitalization and offers insights for future research on supply chain digitalization and its sustainability implications.

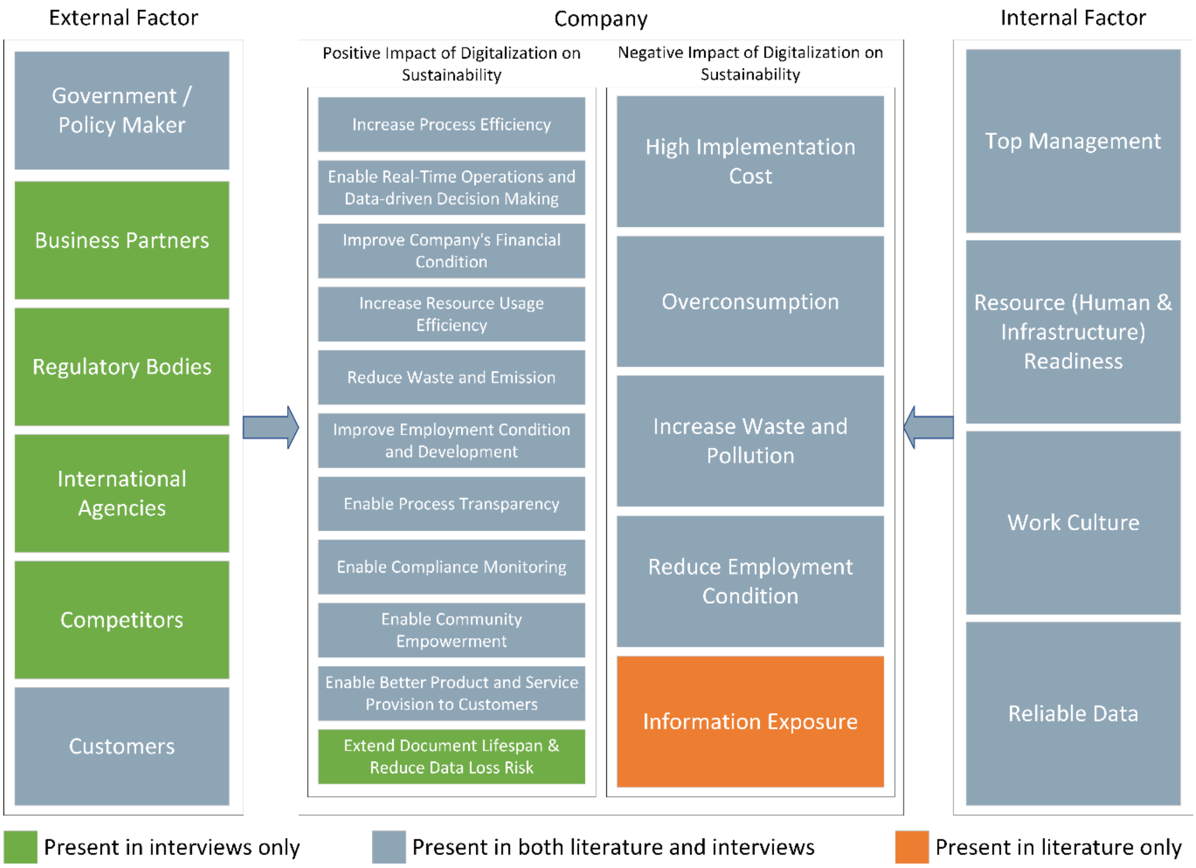

Figure 5.1: Framework of digitalization and sustainability in supply chain

6 Conclusions

6.1. Summary

The impact of digitalization on supply chain sustainability is a complex issue, with both positive and negative consequences. This contradictive issue is highlighted in previous studies by Gebler et al. (2014) on employment in developed and developing countries, and Nantee & Sureeyatanapas (2021) on the effects of warehouse automation tools on electricity consumption. Thus, this dissertation aims to examine the relationship between digitalization and sustainability in the supply chain, while also exploring how digitalization can support supply chain sustainability. To address the research questions, a theoretical framework was developed from systematic literature review (Figure 2.7), which was then enriched with empirical findings from case studies conducted in four Indonesian FMCG companies (Figure 5.1).

Some insights into these factors related to the influence of digitalization on supply chain sustainability have emerged. In implementing digitalization, top management possesses a central role in securing the economic sustainability of the company through alignment between digital solutions and problems, cost-benefit analysis, careful annual planning, and effective leadership of each supply chain section leader. Furthermore, work culture indirectly stimulates employees' skill development and benefits the community socially and environmentally. In addition to government involvement, it not only supports companies' economic sustainability, but also promotes employees' skill development. On the other hand, business partners have mutual beneficial relationships with the company by keeping the companies informed with the latest technology and transferring new capabilities to local firms. In the case of mitigating negative impacts on each sustainability aspect, the companies focus on economic aspects before the implementation, followed by addressing the employee impacts, and finally considering the environmental consequences.

This study contributes to the literature on digitalization in supply chain and offers framework and insights for further research on the relationship with its sustainability effects. To answer the first research question of "How can digitalization influence sustainability of supply chain?", it was identified eleven clusters of positive impacts which were:

1. Increasing process efficiency by streamlining business processes
2. Enabling real-time operations and data-driven decision making
3. Improving company's financial condition by reducing cost and increasing savings and profits through more seamless operations

4. Increasing resource usage efficiency by decreasing raw material, electricity, and other resources consumption
5. Reducing waste and emission
6. Improving employment condition and development by developing employees' skill, eliminating repetitive tasks, and ensuring safe workplace
7. Enabling process transparency by enhancing visibility, traceability, and transparency of the supply chain
8. Enabling compliance monitoring
9. Enabling community empowerment by enhancing community well-being and transferring new capabilities to local firms
10. Enabling better product and service provision to customers.
11. Extending document lifespan and reducing data loss risk

On the other hand, five clusters of negative impacts were identified which were:

1. High implementation cost
2. Overconsumption of resources and energy
3. Increase waste and pollution
4. Reduce employment due to replacement with automation
5. Information exposure regarding privacy and sensitive information

In addition, to answer the second research question of "What are the factors that can influence the relationship between digitalization and sustainability?", this work identifies four internal factors (top management, resources readiness, work culture, reliable data) and six external factors (government, business partners, regulatory bodies, international agencies, competitors, customers) that influence the relationship between digitalization and sustainability in the supply chain. To ensure the successful digitalization, companies should prepare these internal factors, while also maintaining relationship between external stakeholders, such as government, business partners, regulatory bodies, and international agencies, and monitoring the trend and activities among competitors and customers.

This research offers managers a practical map for understanding digitalization impacts, considering both internal and external contingencies presented in Figure 5.1. Moreover, the experiences from each case company can provide insights of potential challenges when adopting digitalization, and effective mitigation practices. From an academic perspective, this research contributes to a better understanding of the relationship between digitalization and sustainability in supply chain.

6.2. Limitations and Future Research

It is crucial to highlight the conclusion with an understanding of the study's limitations.

This dissertation is a qualitative study with a small number of cases that do not have quantitative data regarding the impacts of digitalization on sustainability. In addition, the specific characteristics of FMCG companies as the object of the case study research might not be applicable to other manufacturing sectors. Due to these concerns, biases, limited reliability, and generalization may exist. Therefore, further research is necessary to validate the proposed framework. This involves more cases, both within the similar FMCG companies for literal replication and different types of manufacturing companies for the theoretical replications (Yin, 2018). In addition, conducting interviews across various roles within the company and gathering evidence from external entities, such as distributors, modern retailers, SME stores, and exporters would offer different perspectives on the impacts and contingencies of digitalization on supply chain sustainability.

It is worth noting that the research was conducted in Indonesia, the 12^{th} largest global manufacturing output and the largest manufacturing country in Southeast Asia (World Bank, 2022). While insights from the FMCG industry in Indonesia may represent practices by global manufacturing leaders, there might be biases due to the location of the case companies. In addition, different nations may have distinct policies and regulations that influence the digitalization adoption.

Lastly, the framework's generalizability should be confirmed by expanding across different industries.

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A Appendix A

The appendix contains summary of interviews and email communication with informants from four companies related to the case studies. The name of companies and all mentioned brands and products related to each company are redacted due to confidentiality and replaced with codes. The details regarding codes in the interview summary are provided at the end of this appendix. The sequence of interview summary and emails is arranged according to Table 3.1. All interviews and emails are conducted in Bahasa Indonesia and translated to English in this appendix.

A.1. 1st Interview of Ice Cream Company

Interview with Assistant Engineering Manager for PM Excellence & OEE Improvement (coded as OAM) held on 30 July 2023 09.00 – 10.31 CEST.

1. How is the supply chain process of the product working from initial stage to the final stage?

   The company employs Good Manufacturing Practices (GMP) for food manufacturing, particularly for production quality standard. This comprehensive standard covers raw material, packaging, and goods receiving process from suppliers, e.g., chocolate, peanuts, sugar, etc. In the ice cream supply chain process, when raw materials are coming, they will be separated into allergen and non-allergen categories as it refers to European requirements. This requirement is regulated in GMP.

   When raw materials are coming, they will be received in internal warehouse and external warehouse which is located outside the factory if the internal warehouse cannot accommodate the raw material and packaging volumes. Factory C has one external warehouse. When raw materials come, they will be checked by quality officers by taking samples. If the quality is good, the raw materials will be registered in SAP systems. After that, the raw materials can be used in the production process. When entering the production process, the raw materials are separated into two sections. The first one will be directed to the processing plant section; another will be dispatched to the packing hall. Raw materials that are dispatched to packing hall are packaging materials and raw materials for food outer layers, e.g. chocolate and peanuts. In raw material warehouse, there are three room types which are multipack room (temperature is set to be between -10 C and 10 C), ordinary raw material storage room (ambient temperature), and chilled room (temperature is set to be -5 C).

From the raw material storage room, raw materials are transferred to mixing section. The mixing process involves raw materials such as milk, sugar, vegetable fat, and flavoring. There are several stages in mixing section. All raw materials are mixed and stirred in the tank. After that, the mixture will be pasteurized to 80 C for 3 seconds to eliminate pathogens. Next, the mixture will be cooled until reaches temperature under 10 C (normally 5 C). After that process, the mixture will be stored in storage tanks for maximum 72 hours before entering packing hall which the process is called aging. Then, it will be transferred to freezer and will be cooled until it reaches temperature under -5 to -7 C to form ice crystal. After that, it will be transferred to the filling machine. In the filling machine, the mixture will be shaped based on the products. For instance, PP products will be molded in their cast and will be frozen, then they will be taken out from the cast. For tub products, the mixture will be filled to the tub containers until they are fully filled. Other products like MN will be extruded from the filling machine, then cut to pieces and transferred to cooling tunnel for about 45 minutes before being dipped in mixture of chocolate and nuts and being packed with wrapper machine and put into cardboard box. The cardboard boxes will be palletized afterwards at a room temperature of 10 C, then will be transferred to the cold store which has temperature of -25 C. These boxes are stored in the cold store until they are transported by the trucks to the distributors.

2. Is there any digitalization implemented in this step of the supply chain process? How is digitalization being implemented?

   Digitalization process in WL is still in pioneering stage. One of the examples is making dashboards with PowerBI for processing the data before they are inserted in factory dashboard. Since FMCG factory has waste as the main public enemy, we have Power BI dashboard for waste monitoring to know where the waste is mostly located. However, the input data to the dashboard is still manually recorded. For instance, an operator handles machines in one of the workstations (it can be filling, freezer and packing hall station which each waste has its own category) and he/she will record manually using paper and pen, then the data will be transferred to an administrator in production section to be inserted in the PowerBI platform. When the data is already processed in PowerBI, we can know waste tonnage and can be converted in money value. However, it is not always a kind of waste with highest tonnage has higher money value loss because of different SKU and products. Therefore, the waste should be inspected in volume and money value of Euro. From the data, we can know which section we should improve to reduce waste. The type of waste which is recorded is the ice cream mixture. For instance, rejected products due to failing to be picked by robot are gathered in a container, then will be weighed, and recorded. The record will be inserted to the dashboard. The next step of digitalization is the implementation of SMS-D. This system will be deployed to machines, so if there is any breakdown, the system can identify the breakdown by sensors which are attached to the machines. In addition, the system can read the machines condition in real-time and will be recorded to the servers. Therefore, it will be no manual input by the operators. Moreover, SMS-D can track both the upstream and downstream side of robot area in production line. If there is trouble with the robot, the SMS-D will read duration of robot's breakdown and robot's part that has trouble. Currently, it is not implemented yet and integrated with other machines in production line. The other digitalization is stopline monitoring using Power BI to know which machine unit that has most breakdown loss. The input data for the dashboard is still recorded manually and compiled by an administrator in production section. The output for the dashboard is to be calculated with overall equipment effectiveness (OEE) calculation. The dashboard will show target and actual breakdown, monthly and year-to-date mean time to repair (MTTR) and mean time before repair (MTBR), maintenance time, and stop classification. The impact of the dashboard is we can know which machine has the most breakdown and needs to be tackled.

Another digitalization effort is changing paperwork to be paperless. This digitalization is related to safety and quality. The first one is related to safety which is an event report platform to inform if there is any near-miss event, accident, or unsafe condition in the workplace. Before using the platform, event report uses papers to record the events.

The second one is a work permit request application for contractors which uses a web-based platform. The impact of this platform is expediting the contractors to be permitted to work in the workplace, but the money value of this application's effect is not quantified yet. Before this platform existed, contractors needed to look for signatures from key persons in different places, such as supervisor, assistant manager, and safety officer. This activity took 2 hours to complete. By using the platform, contractors only submit the permit to the platform and wait to be approved by those key persons. Besides, it also reduces 2 hours of non-value-added activity which impacts overtime budget reduction.

The third one is emergency work order (EWO) web-based platform which connects production personnel to engineering personnel if there is any work request related to spare parts and support from engineering department. Before the EWO platform implementation, the work requests were documented by paper forms which need to be filled by information, such as problem root causes, value analysis, and conclusion of problem causes. These paper works were mostly not archived properly. For the implementation, each machine is equipped with one tablet. If there is a breakdown, make loss time more than 30 minutes, and needs spare part or support from engineering department, the operator needs to submit EWO with the tablet. In the platform, the operator needs to fill 5W + 1H to capture the whole breakdown information to the engineering department. After the information are filled in, there is detailed time information which need to be filled regarding breakdown time, technician waiting time (if this is high, there is work queue in engineering department meaning lack of manpower), operator waiting time, spare part waiting time (if this is high, there is a shortage of spare part), analysis time, repair time (if this is high, there is a major breakdown), and cleaning time. Currently, this time information is still manually filled and will be filled automatically when SMS-D is already implemented. In addition, this time information is used to analyze the improvement. The improvement is not always about installing new machines since it will be very costly. Therefore, this information needs to be analyzed to find the root causes to prevent any unneeded investment. As additional information, all information in EWO platform is still manually input, so it digitalizes the paper works.

The fourth one is Computerized Maintenance Management System (CMMS) which digitalizes task list and maintenance schedule of all machines' parts. The maintenance schedule can be different in period, such as every 3, 6 or 12 months. Before the implementation took place, each maintenance task should be controlled manually in a calendar which was made in spreadsheet application. This manual work took a lot of time since there are thousands of tasks and need to be sorted manually, then need to be printed and check listed one by one. By using CMMS, the maintenance personnel insert the task schedule information to the database and the tasks will be scheduled automatically. In addition, those scheduled task lists can be transferred to tablets of the engineering team. The tablet will show the checklist of the task, can insert pictures and maintenance time duration, and input the replaced spare parts which will update to the spare part room storage system. The impact of this implementation is eliminating non-value-added activity which are tracking and printing the task lists one by one.

The next digitalization development will be focused on SMS-D implementation and process parameter project. The process parameter project will focus on recording process parameters (e.g., mixture temperature in several points) in machines by using tablet which is installed on each machine. The input process will be done by machine operator. Moreover, the project also emphasizes maintenance which is done by machine operator, such as changing machine oil, filling lubricants and tightening bolts. This process parameter project is not running yet and is still in the development phase.

The main utility of Power BI is displaying performance. Therefore, the function of Power BI is to know which machine has the most breakdown and location that has highest amount of waste. For example, Machine A has higher breakdown rate of 6.15% than target breakdown rate of 5% because of robot breakdown. In this case, robot needs to be checked why it always has breakdown and a lot of loss by checking EWO first. In EWO platform, we filter the work order by Machine A and robot area to see work order requests from engineering and production personnel. From those filtered data, we can do 5 whys analysis and root cause analysis why the events happen, is it due to the program or design weaknesses. From the analysis, we can do the next action. For instance, there is a part that is not replaced yet for a long time, such as worn out bearing which will impact to repair maintenance cost. Another example can be due to incompetent operator which needs to do retraining with the robot manufacturer. Another example can be a lack of design which needs more investment in capital expenditure (CAPEX) to improve the robot design. The loss time target for each example can be projected and quantified to money value in term of OEE improvement which can be reducing labor cost, or electricity cost and water cost based on cost per unit and improving the production output.

Savings from mixture waste is the easiest one to calculate because of its clear quantification. For instance, robots have the highest waste in the waste dashboard which can be impacted due to high breakdown, so that the products are not picked by the robot. From the dashboard, we can know kilograms of the waste which can be quantified to money value by multiplying the kilograms of waste with the SKU product's price. Therefore, it is easier to quantify the waste to money value. If we relate the case to sustainability, the Power BI dashboard helps to identify which parts to be improved in order to reduce business waste.

3. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?

   Input data for the dashboard is still manually supplied from paper documents. There is a possibility of missing input data due to the operator's error. Therefore, the data may not be 100% accurate. For instance, there is similar data in robot and tunnel area which can be inaccurate due to missing input data caused by operator's errors. The same case can happen in waste dashboard because the input data is still manually input, so the risk of wrong input, wrong point of waste documentation, or other human error can happen.

To tackle human error from manual input, the implementation of SMS-D should be executed because the system can extract the data from the machines.

4. What and how are the factors that lead to the successful implementation of this digitalization?

   One of factors that make the digitalization implementation run successfully is standard operating procedure (SOP). Since digitalization changes work culture, such as changing from paper works to inserting data digitally which will impact to procedure change. For instance, since production personnels are under the manufacturing department, we need to communicate and coordinate with the department to inform them of the change in procedure due to the improvement. Next, training needs to be conducted in all shifts and needs to be fully attended by all machine operators. This training will impact EWO compliance submission, so the data can be filled in completely. The same case also happened in waste monitoring. Therefore, success training is one of factors that support successful implementation of digitalization along with clear SOP making.

   The other factor is the system itself. To develop the digitalization system, the company uses a third-party contractor. In the earlier deployment stage, the system needs to be improved, especially input from operators and users related to difficulties, and input from engineering team related to things can be improved for the system. Then, these inputs will be shared to the contactor. As long as the contractor is responsive in resolving the inputs, this will improve user engagement. Therefore, collaboration with contractors is one of key success factors in implementing digitalization.

   Other key success factors can be hardware (in this case, tablets, servers, Wi-Fi). There was an incident related to the interrupted Wi-Fi network which caused loss of input data for several hours and it impacted historical data recording.

5. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?

   Digitalization positively impacts sustainability, such as reducing waste, breakdown loss, and improving OEE. Installing robots is not digitalization, it is a part of digital transformation. Digitalization will remove non-value-added activities. For example, activities that involve manual input will be replaced by automatic and real-time tracking of the system. This improvement will make operators can do other things or can be trained to analyze the data, do Kaizen, etc., which will have more value.

Power BI is not only for displaying performance, but also encouraging to do improvements, and facilitating data extraction, so there will be no more individual data extraction from different files.

The work permit web-based platform is not only cutting process time of waiting signatures, but also reducing overtime budget. In addition, work permit web-based platform and EWO web-based platform enhance documentation lifetime. This becomes important in the event of a major accident, as the platform enables seamless tracing from one source of server. By using server, lifetime of documentation storage will be longer than paper-based documentation storage. Moreover, when looking for data in paper-based documentation storage, we need to check it one by one. Meanwhile, using these electronic platforms, everyone can access them at one time which will ease investigation. For example, if there is a breakdown, we can trace the historical record of breakdowns and the relationship between breakdowns by using EWO platform. This will expedite analysis and investigation if there is major accident.

CMMS enables us to trace parts that are used in the maintenance to see the historical trend while also facilitates spare part tracking to know in which machines the spare parts are used. In addition, this platform can minimize lost spare parts due to its traceability. Moreover, when the factory receives and stores spare parts in the inventory room, every spare part should be registered in the system with information details, such as in which it will be used, and its usage (is it for maintenance or breakdown?).

6. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?

Regarding operations safety, there is a standard clause from global level of the company which triggers the factory management to execute the derivative rules. For instance, before EWO web-based platform implementation, there is no further analysis of paper-based forms, and the forms are thrown away. This event affects operator engagement to raise breakdown issue using EWO which impacts to loss of analysis. Moreover, when people from the company's global level want to investigate the breakdown loss, the factory management does not have the data due to the mentioned event. This will impact to disapproval of CAPEX proposal because there are no details of breakdown loss analysis. From this event, factory management started to change the workflow by placing tablets in every machine to digitalize the request of EWO. Therefore, the company's global level of management has a role to push factory management to implement the rules and policy regarding this issue. Then, factory management will develop the policy using training, innovation rewards and incentives to drive people in the soft floor to familiarize in using the digital platform. We also use training absence to trace historical data of people's training.

Regarding the infrastructure, we need to prepare the devices, such as tablet installed in each machine and Wi-Fi is installed when doing the training, so the training participants can practice immediately with the devices.

Benchmarking with other company's factory in other country, such Turkey. One of the benchmarking examples is factory dashboard which uses PowerBI in one platform, so the dashboard is not scattered in different departments. Other example is EWO which Turkey's implementation is more disciplined in the execution. Benchmarking between company's factories is easier as the data can be shareable. We also benchmark with competitors to know why they have better performance. However, this is limited due to unable to share data.

In terms of government involvement, there is no push from the government to digitalize the process. Regulation bodies like BPOM (National Agency of Drug and Food Control) audits ask for documents. When there is an audit, the company should compile the document which is difficult if the data is not integrated yet. This difficulty pushes the internal company to gather documents in one platform of Sharepoint or another platform like EWO and CMMS if it is needed. Safety audit Bureau Veritas Audit also asks for documents. If we have one place to centralize the document storage and have a digital platform, it will ease the company in supplying the documents to the auditors.

Next strategy is implementing SMS-D. SMS-D is from company's global level of managements and has a function to do real-time monitoring of all machines. Besides SMS-D, there is also B-Apps which is develop by company's global level. B-Apps have the same function with already developed web-based platform, such as work permit (E-PTW), EWO, and CMMS which are self-developed by the factory personnels. These platforms have been running before the implementation of B-Apps. However, it is not yet clear about the fate of those self-developed platforms since there is redundant application with B-Apps. In addition, there is also consideration if the B-Apps can facilitate the operators easily.

7. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?

   No unsuccessful implementation happened in my work section.

8. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

   Next plan is SMS-D implementation. We also will improve EWO to expand its features to check safety and quality. Q-EWO (quality EWO) is platform to report if there is any incident in quality, such as loose bolt. Q-EWO will be digitalized with the same platform as EWO since it is currently reporting in paper-based forms. S-EWO (Safety EWO) is to report if there is any safety incident, such as stumbled, nipped by the machine. Currently, it still uses paper-based forms to report incidents.

   Management of Change (MOC) is to record and compile if there is any change in supply chain process, such as products, machines, and safety. This platform is made to inform new personnel regarding the record of process change in his/her position. This platform impacts factory and company's global level in terms of knowing change record in the factory process. Before implementing any change, the change will be checked and approved by experts in the factory, manufacturing manager, engineering manager, and head of factory. If the change is approved, the project can be executed by the contractors. MOC platform also records if there are any changes related to products' ingredients and volume.

   The company is not doing top-down management. If there is any innovation at a low level of the company, it can be executed. However, it is still not clear if there is any redundant implementation if the company's global level has the same application for the same issue.

A.2. 2nd Interview of Ice Cream Company

Interview with Assistant Engineering Manager for Electrical & Digitalization (EAM) held on 4 August 2023 12.00 – 13.06 CEST.

1. How is the supply chain process of the product working from initial stage to the final stage?

   Supply chain starts from production planning. After that, the company will buy raw materials and packaging through SAP. Those raw goods will be received in the factory, registered as Goods Received in SAP, and stored in warehouse. In the warehouse, raw materials and packaging will be separated either to go to mixing room or packing hall. Raw materials which go to the mixing room will be used to make water ice or ice cream mixture which will end in packing hall. After mixture is ready, it will be transferred to packing hall to be formed according to the products. Next, the products will be palletized after being packed in cardboard box, then the products will be stored in the cold store.

There are several difficulties in the supply chain process:

a. When using raw powder material which is packed in 1 kg package, we do not use all of them at one time. Sometimes, we use only several grams of them in one process. This makes usage record in SAP different from actual usage. Moreover, inventory taking is not done every day, but at the end of week. This inventory taking will check the remaining raw powder material. To tackle this issue, we made a system to help us in recording the partial usage of raw materials in one batch and one day to know the actual usage of raw materials. However, the system is still in development.
b. Manufacturing Execution System is like SAP which is an integrated end-to-end platform to track goods movement from receiving raw materials, mixing process, product packing, storing in the cold store, and freighting to distributors which guarantees the data reliability. Moreover, this system also covers maintenance and customer input (in this case, complaints from customers regarding products). Additionally, if the data is integrated, the data can be basis decision making, such as in developing new product. Without this system, there is still a problem of data matchmaking from one process to another, such as missing raw material usage. Currently, it is still manually handled for customer complaints. However, the company has not reached that stage yet.

SMS-D is focused to calculate OEE of machines exclusively in packing hall to know work effectiveness in lines of machines.

2. Is there any digitalization implemented in this step of the supply chain process? How is digitalization being implemented?

   We use PLC to control all machines in packing hall, utility, and mixing room. Regarding automation, automation in packing hall is still half implemented since there is a stand-by operator to start and stop the line from mixing, filling, and packing hall, supervise if the machine has errors and products are not picked by the robots. We have a Tea Based Beverage (TBB) plant that has a fully automated system and has no personnel in the machine line, so the packing hall is dark. This is because the TBB machine line is simpler than ice cream production line. The ice cream production line has been established since 1992 and some machines in the packing hall has been used for more than 10 years.

We also developed applications related to reporting, such as EWO, CMMS, and Digibox. We also digitalize process to make permit to work (PTW) for contractors using web-based platforms. In this platform, contractors can submit required documents, such as safety plan, work to be done, workers, certifications they have, and risks of work. If the required documents are fulfilled, PTW will be approved by working area supervisor, employer, working area manager.

The cooler for ice cream is using ammonia and controlled by utility team using SCADA. Utility team does not control only ammonia, but also electricity, water. We make application to control SCADA using mobile device instead of controlling it from human-machine interface (HMI) on computer, so the team does not need to go to utility control room. However, the control permission from mobile device is currently turned off and only can review due to safety reason.

Before the platform is made, waste monitoring is running on paper-based form. Waste monitoring uses QR code in each working area to identify and report the origin area of the waste, its weight, and its SKU. The platform enables to see the data regarding daily and weekly waste generated.

Before releasing finished goods, quality controls, such as metal detector, weight & volume checking, finished goods condition (is there any tear, scratch on the wrap?) are implemented. However, the current process still relies on manual sampling to retrieve the data. The sampling data for quality check is entered in an application named SPC. Then, the data is extracted to Sharepoint and used as a basis to release the finished goods.

3. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?

   Adding robot for packing process replaces one personnel in packing hall. Meanwhile, it is also impacted engineering team due to more robots to be maintained.

   Regarding application, in this case waste monitoring (no issue in installation), when train the users, changing personnel's habit from filling paper-based form to filling application in a handheld need step-by-step. First time use users are not familiar with the handheld usage, consider also still in development stage, so then it is a time range for developer to fix and improve the application if there is any additional input and feature in the application based on user feedback. From operator/user side, it needs time for users to be familiar with the application.

   SMS-D replaces the system that still needs manual input which is named SMS-P (still use papers in its operations). SMS-D uses tablets for the application in its operations. In the ice cream plant, there are more than 20 lines. Currently, SMS-D is already implemented in one line, not fully deployed yet. We cannot switch immediately to SMS-D. Therefore, the line that has already implemented SMS-D is also running SMS-P since it is still in transition phase to implement SMS-D. Currently, both are still redundant in the operations.

SMS-D is an application from the company's global level which has fixed, and rigid format of system and the details cannot be modified without authorization from company's global level. However, there are several pieces of information which cannot be provided by SMS-D, but can be provided by SMS-P. In this case, we need to develop another application to show information that is used to be provided by SMS-P. The information which can be inserted to SMS-D is machine breakdown reason. Meanwhile, in SMS-P, we can insert more information, such as operator name (to check attendance and wages which are based on production output). SMS-D's advantage can provide real-time data while SMS-P data can only be retrieved at the end of shift which means we do not know operational data that is ready to be processed for 8 hours until the shift is finished.

Regarding waste monitoring in terms of making the users familiar with the system, the leader of the section should push his/her subordinates to be familiar in operating the new system (using top-down approach management).

4. What and how are the factors that lead to the successful implementation of this digitalization?

   The human factor is one of the factors, especially in making the users familiar with using the digital system, e.g., using tablets.

   Technology solution is matched with the problem. Sometimes, we already develop apps, but the users do not use the apps.

   The goal of this digitalization is to get Lighthouse certificate and reduce human resources. However, ice cream is difficult to reduce human resource as the process is too complex and there is any incident, it will be difficult if there is no stand-by person.

   Infrastructure readiness is inevitable. If we want to implement digitalization without any ready infrastructure, it does not make sense.

5. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?

   Energy monitoring is done by the utility team, exemplified by controlling motor speed by using PLC to match with its workload need (by regulating the electricity power and frequency). This is an example of an energy saving application.

Every year, the company has programs to make savings. Sometimes, the saving is not happened because the machine solution always has breakdown and did not go according to plan. This case refers to robot that replaces human in the packing hall. Currently, the robot is still in use in the operations, but the projected saving with the robot is not happened.

Indeed, digitalization has big investment value in advance.

Waste increment and overconsumption happened in the first installation of the new machine. This happened because of the first installation and adjustment of the new machine. This happened in the grip machine to pick and move products.

In every problem solution, the design of the solution should be adjusted according to the problem's needs. If not, the advantage is not happened. Meanwhile in the factory case, there is always lack of input from many users in the plant. The current solution is strictly observing and ensuring the design and its details, doing more supervision on the contractors' works, ensuring the contractors have the right certification.

For users' familiarity with the digital system, it needs to do top-down approach management to ensure all subordinates obey the new system.

6. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?

   The company has a global project which must be implemented in a designated site, e.g., Southeast Asia, Europe. The company's global level sets targets for project execution, and conducts regular reviews, either on a monthly or weekly basis, to monitor progress.

   The factory management initiates projects mainly focused on cost savings, with an annual target set for the factory, such as reducing budget which drives those improvement projects. Additionally, there is also KPI that must be met for these objectives.

   There is also regulation from government and rules of the company in local level. However, there is no specific example regarding these rules.

7. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?

   There was a project called smart toolbox which was started before COVID pandemic. This project objective was recording who took and return tools that were used in the packing hall, e.g., screwdriver, hammer, measuring tape, etc. We gave the project to a vendor and had the result of prototype. Before the prototype was being mass produced for other lines, COVID pandemic happened. Due to COVID, there was a design change to add UV light in order sterilize the tools. When the new design made, the COVID was over and UV light was not needed anymore. Next, the design changed again to remove UV light from the design. Another problem was the vendor gave the project to another subcontractor and the materials to make the project were increased. This made the material changed to be the cheaper one and had low quality. Another problem was the purchase order for mass producing the toolbox was already fixed and could not be modified.

The factors of this failed implementation were human factor, COVID situation, limited budget, and raw material price.

8. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

   The company has a goal to get Lighthouse certificate which requires integrated system, such as MES (manufacturing execution system) and fulfillment of sustainability obligations. Currently, digitalization is fragmented in small areas of the production system, with the data dispersed and unconnected. It is better to consolidate these dispersed elements into a unified system to generate one true data, as opposed to current situation where data is scattered and separated, making us challenged to know which one is the true data.

A.3. 1st Interview of Powdered Beverage Company

Interview with Business Analyst Manager (BAM) held on 7 August 2023 08.00 – 08.43 CEST.

1. How is the supply chain process of the product working from initial stage to the final stage?

   The supply chain process starts with procurement, initiated with price negotiation, and supplier identification. Upon receiving materials from suppliers, we process the materials accordingly by conducting quality control (QC) for both raw materials and packaging materials. There are also QC processes in several points in the production process. When production is finished, finished goods will be stored in finished goods warehouse and transferred to distributors based on sales division’s orders. We also sell directly to modern markets and distributors. Distributors will handle several modern retailers and traditional markets. For modern trade market in Jabodetabek, it is directly handled by the company.

2. Is there any digitalization implemented in this step of the supply chain process? How is digitalization being implemented?

   In procurement, we have created a platform for suppliers to submit tenders and all required documents. They can also fill their profile. However, this platform is not publicly available and only shared with potential suppliers.

   When raw materials arrive, they will be registered to WMS to know inbound and outbound raw materials. WMS is connected to Oracle inventory. For office items, machines, and item purchases, there is an asset enterprise planning which is digital. Communication between users and procurement department from order until procurement process is done in digital way.

   In production, we have a weighing application that ensures raw material weight corresponds with previously inserted formula. There is formula management to manage all products' formula including currently active formula, previously used formula, replaceable formula, and replaceable raw materials. This also includes a database and its processing. Packaging also has its own management system. These management systems are integrated with Oracle System of Production and Inventory.

   We have SMS-I, a smart manufacturing system to extract machine performance data, such as runtime and production outputs.

   For outbound goods management, we have Oracle Order Management which manages the process from goods order up to the outbound process. We also use RPA to insert orders from the B2B market, which is modern retailers. This RPA is extracting data from specific modern retail company websites, where they put orders to manufacturing companies, and transferring this order to Oracle system to be registered as a purchase order from this modern retail company. Then, this order will be received by the finished goods warehouse and will be sent to distributors and outlets which have placed orders previously.

   In the finance division, we have a finance portal to input down payment request, money realization, and budgeting.

3. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?

   Robotic Process Automation (RPA) is implemented to decrease manual work of employees. This implementation faced resistance from employees who complained about the robot frequently crashing which were often trivial issues with available solution. Since the employee was reluctant and felt he/she would be replaced by the robot, the employee continuously raised the issue and said that the robot was not reliable and needed to be improved. This project needed several months to make the employee familiar with this new implementation. Although the implementation resulted in cutting employees, not all employees were affected, as there was a need to ensure the seamless operation of the robots and immediate solve in case of issues with the robot.

To tackle the resistance, we need support from higher management which used this RPA. We also verified to the employee who filed the complaints about how often the issue happened and the reason of the issue. Sometimes, the issue happened due to users' usage. We also re-educated the users regarding the system and had the support from the user's top management. In this way, the manager was convinced that the system was running well despite there was user reluctance. In addition, the users were convinced by their managers to collaborate with the machine.

4. What and how are the factors that lead to the successful implementation of this digitalization?

   Requirement for the application should be appropriate with the problem, so we know how the application will be beneficial for the company. We also need support from top management, including funding. This support is also applied to the problem with employee reluctancy.

   Apart from the mentioned factors, users must understand the detailed business processes and their objective. In RPA case, the primary goal is to eliminate all repetitive processes and make the robot do these repetitive tasks. We also examined the business processes to identify tasks suitable for automation and those requiring manual adjustment. If the users understand their needs and the system capabilities, they can independently operate the system without IT team support.

   For the top management, they need to know the purpose of each technology implementation, set time targets for new system implementation, identify potential sacrifices during the implementation. In RPA case, RPA needed to sacrifice human resources since the technology replaced it.

   Ensuring the user's team engagement is essential for team retention in the project. Meanwhile, maintaining stability of the IT team in handling project is important. Frequent reassignment of the IT team can impede the learning curve of the IT team about the new business process.

5. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?

   Before talking about the positive impact of digitalization, it is important to underscore that the cost benefit calculation is essential to assess if the project is economically beneficial. There is also concern of increasing electricity cost and processing power due to addition of new PC when implementing automation. Moreover, the current development of a best route algorithm in sales division has implications for the environment while optimizing efficiency. Digitalization also reduces paper usage despite small financial value. In the finance department, we introduced a digital document signature platform, enabling users to sign documents securely and legally using tokens while eliminating effort to seek people who need to sign the document.

It is important to underline that the good environmental effect is just spillover of digital implementation, with main objective on improving company's business in economic terms. Additionally, increased awareness of technology is fostered through innovation challenge event in the company, inspiring everyone in the company to implement a technology in their job.

There is also a plan to trace packaging scrap in waste management which is not implemented yet. The waste will be directed to small medium enterprise for processing and transforming it into more valuable products.

About negative impacts, robot implementation needs processing power, consuming more electricity. In addition, the economic benefits derived from robot usages outweigh the electricity cost. Another concern due to robot usage is the reduction in human resources, resulting in a few layoffs and cancelations of contract extension. To overcome this issue, we prepare new positions for affected employees. Another option is giving training for the person to collaborate with the robot. Mostly give training to prepare company's human resources in digital era. It is worth highlighting that further investment in processing power and security requires additional human resources to maintain the applications.

6. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?

   The main internal factor is the need for top management to enhance the company's efficiency and stay abreast of the latest technological developments. This emphasizes the need for faster data retrieval and reporting processes. Additionally, the company holds an annual event that embraces innovation and triggers employees to revisit their business processes, identifying areas to be improved by digitalization. In addition, the HR team makes a program to make employees more aware with digitalization.

   Regarding the strategy, the company creates an annual strategy plan with specific objectives, breaking it down into sequential actions and developing a holistic architectural framework to achieve these objectives. These approaches ensure tidy steps, integrated data, and seamless integration.

There are many external factors that influence and drive the implementation of digitalization. One of them is the market. Market means customers and suppliers of the company. On the supplier side, we consider how global economic and geopolitical condition, such as US-China trade war, may impact the material supply to the company. We also consider external technology development by evaluating their compatibility, benefits, and stability for integration within the company. In addition, the upcoming global economic outlook is also considered in our future planning. Shifting customers' shopping habit also makes the company enter many online marketplaces which are managed by e-commerce division.

7. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?

   An example of unsuccessful implementation was the introduction of demand planning forecasting feature in Oracle ERP. This happened due to many manual inserts from brand operations responsible for demand planning. These manual entries were done due to factors beyond historical data and forecasts. These factors were intuition based on knowledge and experience from individuals. Due to this issue, the application was not used anymore and currently, they use Excel application which still works for them. Notably, certain manual inserts were made to focus sales programs on specific regions. Therefore, forecast output by machines had to be adjusted to accommodate these manual interventions.

8. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

   The company's next plan on digitalization is focused on the company's needs which are improving efficiency, productivity, and data integrity. This objective will foster better collaboration in the company because of more integrated data. In addition, data integrity yields to better economic performance due to faster time of data retrieving.

A.4. 2nd Interview of Powdered Beverage Company

Interview with Production Manager (PRM) held on 23 August 2023 04.00 – 04.44 CEST and 29 August 2023 03.30 – 03.57 CEST.

1. How is the supply chain process of the product working from initial stage to the final stage?

Supply chain operations starts from planning which are demand and supply planning. Demand planning is done by the brand operations team, and supply planning is done by PPIC. Demand planning is under marketing team because our products have made to stock characteristic which is influence by market trends. Marketing will make sales forecasts based on market research results and historical sales data which are done by the brand operations team. This sales forecast covers all items and SKUs in money value (Rupiah unit). Forecast has two types which are annual forecast and rolling forecast. Annual forecast is used for planning in the next one year and usually used in the budgeting process. However, rolling forecast is used for production schedule execution and updated monthly or every 3 months. Forecast that is already done by brand operations then will be translated by PPIC team into product unit. When the PPIC team plans the production based on previous forecast data, the PPIC team needs to consider the required raw materials and packaging materials to execute the production. In addition, the PPIC team will make 2 documents based on brand operations' forecast which are production schedule and purchase orders if there are needs to buy raw materials and packaging materials. Production schedule will be used by production operations team while purchase orders will be used procurement team.

Purchase orders will be the basis to purchase the needed raw materials and packaging materials to suppliers by purchasing team. The objective of the purchasing team is to maintain an adequate stock of raw materials and packaging materials aligned with the production requirements. Purchased raw materials and packaging materials will be stored in the warehouse of raw materials and packaging materials. These provided materials will be synchronized with the production schedule, executed by the production team. Regarding the service level agreement target, PPIC has a target of fulfilling 98% of orders from brand operations while the production team has a target of fulfilling 95% of orders from PPIC team. The production team has a lower service level agreement (SLA) target because there is buffer stock in finished goods warehouse. The production team then executes the production schedule to produce finished goods which will be transferred to finished goods warehouse.

The finished goods warehouse has 3 main tasks which are receiving production output, managing inventory (warehouse management) and carrying out delivery of finished goods in exact amount, on time, with right quality. There are several types of customers which are modern outlets, distributors, providers, export buyers. Modern outlets in Jabodetabek (Greater Jakarta Area) and Bandung are covered directly by the company's distribution center. Distributors will handle product distribution to regional modern outlets and SME stores according to their service area coverage. Providers are similar with distributors, but they are managed directly by the company. Although it has partnership with a third-party company for the provider's management, the company manages the warehouse, orders, and inventories by using the company's warehouse management system. Export buyers are dealing with finished goods that will be exported.

The production team in the supply chain has several tasks, encompassing fulfilling SLA of production schedule, ensuring productivity, managing production waste, ensuring compliance with rules of food safety, and safety, occupational health, and environment, providing necessary human resources, and implementing digitalization in production process. Production schedule is released weekly that is usually called weekly work orders. Productivity is not directly related to production outputs, but it is evaluated by considering the effectiveness of production cost and its overhead relative to the production plan. Productivity is equal to production output divided by production input. Production output refers to successfully produced finished goods which are converted into tonnage or kilogram units. Meanwhile, production input has many factors to be considered such as human resources, electricity, machine depreciation and others. However, the company only considers human resources' manhour due to its larger cost proportion. Therefore, KPIs of production team are fulfilling SLA target of 95% production schedule and periodically calculating productivity by dividing kilograms of finished goods with human resources' manhours. Production waste is also controlled. Production waste refers to wasted raw materials and packaging materials during the production process. Compliance with rules of food safety and safety, occupational health and environment are also monitored by the production team. In the company's production process, there are still a lot of people, and it is not fully automated. Therefore, we need to ensure the human resources' readiness to support SLA target. Additionally, when there is an annual forecast from brand operations team, production team needs to review annual production capacity regarding machine capacity and readiness of skilled human resources (machine operators) for upcoming year,

2. Is there any digitalization implemented in this step of the supply chain process? How is digitalization being implemented?

The production team uses the Purdue Model concept in implementing digitalization in the production process. Within the company's production team, there are 5 internal production teams and 1 toll manufacturing team.

A current project within the production team is the implementation of manufacturing execution system (MES). This project is applied to all internal production teams. Regarding the implementation of Purdue Model concept, it does not necessitate the fulfilment of all bottom levels of the Purdue Model pyramid as the company has had ERP system for the past 20 years. The MES initiative began in 2015 and the company chose to self-develop its own MES. Although there were many third-party vendors that provide MES, it is hard to implement in the company, as customization to align with the company's business processes and its details. The MES is designed to digitally record physical activities that are happened on the shop floor, including its actual runtime. Before MES implementation, runtime and downtime data were manually recorded on paper, creating the need to manually recap the data.

The first step in MES implementation is digitizing previous paper records by inserting data in tablets, followed by collecting data directly from the machine's operational technology into the IT system of the application. The MES facilitates real-time and accurate representation of the shop floor, enabling analysis and improvement of issues, such as runtime analysis and downtime. The MES includes SMS-PL and Wonderware to synchronize OT and IT. MES comprises of several software, not just one standalone software. In addition, the MES needs OT and IT. OT is hardware which is embedded in a machine which collects and acquires data. IT is an application in production process for the MES, such SMS-PL and SMS-I. Therefore, we need to synchronize both tools by using intermediary software.

Before implementation, we benchmarked several cases. In the company's case, we first developed the IT system. The challenge in IT system development was how IT systems and applications can completely capture 100% actual business process as detailed as possible which is very complex. For instance, schedule arrangement and production sequence for product N needs to consider optimal combination of product container washing to achieve the most efficient production process. The application must be able to accommodate these complex needs to minimize the number of washing process. Another complexity is every product has its own sequence of production. This customized order of production should be considered in designing the application. Therefore, there should be a business analyst that understands all details of physical activities on the shop floor, so we can closely mimic the application with actual activities on the shop floor. In addition, it is crucial to have a balance, avoiding excessive rigidity in developed applications, as an overly rigid application will be unusable. In conclusion, the main challenge in designing an application for a production process is to perfectly capture business processes on the shop floor and translate them into an effective application model.

3. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?

The challenge in designing an application for a production process is to perfectly capture business processes on the shop floor and translate them into application models that we develop. For instance, schedule arrangement and production sequence in producing product N needs to consider product container washing combination to get the most efficient production process while the application must be able to accommodate these complex needs to get minimum number of washing process. Another complexity is every product has its own sequence of production. This customized sequence of production should be considered when making the application. To tackle this challenge, we need a business analyst to ensure that the application closely depicts the actual production process on the shop floor. The manager forms a team that consists of IT developers and the users. IT developer comprises of business analyst and developer (outside production team) which have programming ability to translate physical activity on the shop floor to coding in the application. In addition, the business analyst is also an integrator and knows all the details of the actual business process on the shop floor. Meanwhile, the user is supervisor from production team and admin that has task to input runtime data from papers. The objective of forming this team composition is to ensure that all details in the actual shop floor process can be completely depicted. Both parties must meet intensely (currently doing a biweekly meeting) to update their progress for the production manager. The business analyst will analyze actual business process while the user confirms the result analysis.

The 2nd challenge is how to educate people on the shop floor. IT people have developed an application which has closely mimics conditions on the shop floor. The problem is people on the shop floor are not familiar with using the tablets and how they can learn to use the tablets. In this case, young people on the shop floor have more awareness in using the devices, so the learning effort to use the tablet is not difficult. Meanwhile, senior employees on the shop floor have difficulty in using the tablets, even they felt confused when pressing tablets' screen. To tackle this challenge, the HR team prepares a training series for digital awareness. We make employees familiar with computers and digital tools by designing the training to be online, digital, and self-service. Another training will also be conducted to train employees when the application is ready to be used. There is also a 1 month babysitting step when the application is already used by the users and the business analyst accompanies the user during the actual usage in the production process. If there are 2 work shifts in the production process, business analysts will also stand by in those shifts to receive suggestions from the users and give the solutions immediately. In the implementation process, it is not only the users' ability in using the application, but there is also possibility of bugs in the application. Therefore, business analysts will stand by during the usage of the application.

The third challenge which has not happened yet is synchronizing OT and IT because the variety of production machines' age is big. There is a machine which is very old and a machine that is new. Therefore, not all machines are ready to do data acquisition. In conclusion, the next challenge is to ensure all machines can do data acquisition and stored in the application. The 4th challenge, which has not happened yet, is ensuring data validity and its cleanness to be ready to analyze. It may be required to do cleaning before analyzing the data. Both the 3rd and 4th challenge need experts to suggest the way to acquire the data, so we can know hardware to be prepared.

4. What and how are the factors that lead to the successful implementation of this digitalization?

   Application must completely mimic every detail in the actual production process. If the application is overly rigid and cannot fulfil the requirement in actual business process, the application will be unusable. In addition, the application also should accommodate new products in the future. There was an event when the application could not accommodate new product developments and the application could not accommodate it which affects the production process to use paper and pens again in recording the production data. Therefore, it is required to make applications that align with actual business processes.

   Besides, readiness and mentality of the people are also the concerns. If the people are lazy to learn the application usage, they will not use the application and go back to manual paper-based process. Therefore, having mindsets to change and eagerness to change are important.

   Toughness of system and its hardware are also important. If there are too many bugs, it will be problems in the implementation. In addition, if the hardware sensors do not align with expected acquired data, it will be a problem.

5. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?

   In terms of environment, digitalization reduces paper usage by recording all data on tablets in digital formats. By having more valid and real time data, we can analyze all conditions in the production process to know areas to improve, particularly in minimizing downtimes. All these analyses have the objective of improving productivity and reducing costs. Furthermore, digitalization cultivates the eagerness to learn among employees. This may not be related directly, but this digitalization insists people learn about technologies.

Regarding the drawbacks of digitalization, the cost of developing digitalization is substantial, requiring robust application that can accommodate all needs and requirements of production process. Besides, people who will use it should have eagerness to learn and change, and all hardware and software are ensured to be tough to execute the digitalization. To anticipate the high implementation cost, we had to ensure the developed application closely mimics the actual business process of the shop floor. To do this, the business analyst who develops the application regularly visits the sitework, holding a bi-weekly meeting with shop floor's employees and production team, ensuring the developed application meets actual business process in the shop floor.

Reduced human resources is a concern, especially elimination of menial and repetitive works due to digitalization. To anticipate this, there are several work processes that exclusively employ non-permanent workers. The objective is when there is digital implementation, we do not need to cut permanent employees. We also transfer the affected permanent employees to other work processes. To address this issue, before implementing digitalization, a careful assessment of calculating proportion of permanent and contract workers is conducted to anticipate the potential reduction of workers, considering permanent workers cannot be fired due to the digitalization. In addition, we also communicate in advance to the contract employees that their contracts will not be converted to permanent roles.

When implementing digitalization, learning curve is inevitable, especially during transition period to digital system. This leads to a temporary decrease in productivity due to time and effort invested through training. To address this, a structured plan is essential during transition by providing effective learning and babysitting period. This ensures users familiarize with the system more quickly and more efficiently, while also enables quick issue resolution by the development team.

Digitalization introduces more structured and potentially rigid systems compared to a non-digitalized system. For instance, data recording applications in the production process have fixed sequences of processes and digitally embedded instructions. This potentially limits users' critical thinking as they may overly rely on the digital systems. In contrast, paper-based systems encourage users to improve the work sequence. To counter the drawback, we encourage them to give suggestions regarding the process improvement.

6. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?

   Top management's policies and directions play an important role in driving the company's digitalization. Over the last 5 years, the CEO has encouraged the middle management to familiarize their operations with digitalization, developing significant progress in smaller scope of every department's business processes. Regarding ERP implementation, the company has been implemented since 2000 using Baan, before a transition to Oracle in 2010.

   Regarding resource provision, the company provides the resources with a measurable approach, where each division creates an annual blueprint outlining the next year's digital development plans based on benefits. Cost and benefit analysis is also conducted for each digital implementation plan to check its feasibility, including the ROI of the project. Resources, including funding, human resources, and infrastructure, will be provided to the approved plan.

   The company's innovative work culture encourages the employees to continuously learn and improve their business processes in their departments. Besides culture, the HR department also supports the digitalization with digital awareness program.

   Regarding external parties, there are many suppliers that provide services and products to support digitalization. In application development, the company establishes partnerships with freelancers that have fast understanding to execute the projects. There are also suppliers that can provide products for digitalization projects.

   The government also involves in the company's digitalization journey through Ministry of Industry by providing many trainings and consultancy. According to the government's assessment, our company is categorized as one of the companies that is ready and committed to implement Industry 4.0 technology.

   Although customers' feedback is not directly related to digitalization, the company develops digitalization in the process to achieve data accuracy, including product traceability. This is crucial to support customers' issue on product.

7. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?

In case of unsuccessful implementation, there is no case. However, there was an issue of developing an application in finished goods warehouse. The application development was almost never finished, although the application was utilized successfully in the end.

8. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

   The primary focus of the company in implementing digitalization is cost reduction. We ensure that we can keep our products affordable for the customers.

A.5. Email Communication with Former Digital Transformation Manager of Powdered Beverage Company

Email communication with former Digital Transformation Manager (FDT) held between 30-31 October 2023.

1st Email

Nicodemus Sigit Sutanto <nsigitsutanto@gmail.com> Mon, Oct 30, 2023 at 9:00 AM

To: FDT@gmail.com

Hello Ci FDT,

How are you? I hope you're always healthy in the Netherlands. I would like to ask for your help and inquire about something related to my thesis, as I couldn't find a reliable source on the internet.

Let me share a bit about my thesis. The title is "Digitalization and Sustainability in the Supply Chain: A Gordian Knot?" The objective is to explore the positive and negative impacts of digitalizing the supply chain on sustainability and the internal and external factors of companies that influence the relationship between digitalization and supply chain sustainability. My thesis method is case study research, where I chose ND as one of the cases. I recently interviewed DTM and DTP as part of this. One of the initial findings from my thesis' systematic literature review is that the government plays a role in the digitalization process in the industry, confirmed by the assistance of the Ministry of Industry and GIZ in the form of training, in which MI, CL, and KT, and me participated.

My concerning issue is that among my case companies, only ND received assistance from the government. The other three companies, WL, ID, and PE, which are larger in size and capital compared to ND, did not receive government assistance. Initially, I assumed that there might be specific requirements regarding the size of the company to receive consultation and training assistance from the government, and during the interview with DTM and DTP, no answer confirmed this. However, in my search on the internet, I couldn't find any evidence to support my assumption. The last information I found was that the government conducted assessments to numerous industries prepared to execute Industry 4.0, but there was no specific information about which company can apply or the requirements for receiving government assistance.

Due to your former position as the PIC of digitalization at ND, I would like to confirm this with you. Are there any specific requirements from the government for companies to receive training assistance? And if so, perhaps if there are any documents related to this which I can refer to in my thesis.

That's all I would like to ask. Thanks a lot for your time, Ci FDT.

GBU, Ci FDT. (God Bless You)

(Note: "Ci" is a term of address in Indonesian, similar to addressing someone as "miss" in English.)

2nd Email

FDT <FDT@gmail.com> Mon, Oct 30, 2023 at 11:18 AM

To: Nicodemus Sigit Sutanto <nsigitsutanto@gmail.com>

Hi Sigit,

I'm doing well in the Netherlands. How about you? Wow, you're working on your thesis. All the best for the entire research and writing process. By the way, it is an interesting topic for your thesis, Git.

Let me share what I know. First, to receive assistance in the form of training via GIZ, it is by ND’s networking. ND became one of selected GIZ's partners to receive free customized training. To know how ND can connect with GIZ, I suggest you talk to HHR. By the way, as far as I know, GIZ funding came from the German government, not the Indonesian government. The Indonesian government only gave guidance, granted access to industries in Indonesia, and supervised the program. So, for the GIZ case, we did not get it from the Ministry of Industry (Kemenperin) but possibly from another ministry, either the Ministry of Manpower (Kemenaker) or the Ministry of Education and Culture (Kemendikbud) – please check with HHR. The program or theme coincidentally aligned with "Digitalization," a hot topic then and now, but GIZ focused more on empowering people or human resources, while Kemenperin's focus was on comprehensive industrial digitalization covering people, processes, and technology.

Second, ND could gain access to Kemenperin through networking as well. I spoke to Mr. FI, who was still with Schneider Electric at that time, in Batam during the Industrial Transformation Asia Pacific (ITAP) exhibition in Singapore. I was invited to join Kemenperin's activities. In 2019, the government initiated the "Making Indonesia 4.0" program as one of the flagship programs toward Indonesia Emas 2045 (Golden Indonesia 2045 Vision). From there, I gained access to participate in Kemenperin's programs, such as (1) the Training program for manager of transformation (ND’s two manager went to that event: Mas EMC & Mas EMK), (2) the Industri 4.0 Maturity Assessment program (Kemenperin collaborated with TUV SUD to assess Plant C, looking at the implementation of I4.0, gap analysis between implementation and the desired I4.0 target, and proposed an action plan), (3) the Technician Training program to Batam (one technical person was sent to Schneider Electric Plant in Batam for training & showcasing I4.0 implementation), and (4) the selection and awarding of the Industri 4.0 Award in 2020. In my opinion, these four things were the main support from the government (Kemenperin) to ND.

To answer your question: Are there any specific requirements from the government for companies to receive training assistance? In my view, the requirement is to be part of the industrial community and actively communicate with Kemenperin. As far as I know, Kemenperin is open to all industries willing to participate. Besides training, government assistance also includes tax incentives, etc. From the ID group, IO is its pilot project and it is even prepared to become a Lighthouse of Industri 4.0. For UR, I rarely saw involvement in Kemenperin activities. Perhaps because UR is an Multinational Company which has its own policies and is more bureaucratic, requiring approval from the its global level. Other food companies also involved or they were in the industrial community, including Kalbe Nutritional, Sari Husada, Nutricia Indonesia (DANONE), Otsuka, Lautan Natural Krimerindo (Kapal Api Krimer), Greenfields, Garudafood, and Frisian Flag Indonesia.

I hope my explanation answers your question. Just let me know if anything is unclear or if you have any follow-up questions. God bless you too, Git! :)

Best regards,

FDT

3rd Email

Nicodemus Sigit Sutanto <nsigitsutanto@gmail.com> Mon, Oct 30, 2023 at 5:22 PM

To: FDT <FDT@gmail.com>

Hi Ci FDT,

Thanks for the fast response, Ci! 😀 Thank you so much for your prayers and answers. They are comprehensive and helpful in filling the gaps in my thesis.

I have one more question, Ci, because you mentioned tax incentives. When you were still at ND, did ND receive these tax incentives, and what form did they take? From what I see in the Ministry of Industry documentation, it mentions that there should be cooperation with vocational schools (SMK) to obtain the incentives. Did ND have such cooperation?

Another question, Ci. Besides training and guidance from the Ministry of Industry, what other assistance did ND receive from the government?

Thanks a lot Ci FDT 😛

Regards,

Sigit

4th Email

FDT <FDT@gmail.com> Tue, Oct 31, 2023 at 10:16 AM

To: Nicodemus Sigit Sutanto <nsigitsutanto@gmail.com>

Hi Niko,

You're welcome! Really glad I could help fill in the gaps in your thesis.

Regarding incentives in the form of tax reduction, to my knowledge, there are several potential options for ND. However, as in 2022, ND was still in internal discussions because there seemed to be quite a bit of administration to prepare (which may not be worth compared to the tax reduction amount), and the alignment between the Ministry of Industry or other ministries with the Ministry of Finance as the tax PIC was not finalized yet. So, from ND's side, it's not certain whether they will take these incentives. However, cooperation with vocational schools (SMK) has been actively conducted long before ND actively participated in Ministry of Industry activities. We have a collaboration for SMK students to undergo internships at ND and for recruitment of personnel in the factory as operators, technicians, or administrative staff, as well as in the IT team as part of the service/helpdesk team. Apart from SMK collaboration, there were also tax incentives related to R&D, which are confidential in terms of data disclosure. For accurate and updated information on tax incentives, you can ask HHR (especially regarding tax benefits from cooperation with SMK) or with DTM/DTP to check with the Finance division.

Besides training assistance, it seems there isn't anything else, Git. ND doesn't receive government funding for the implementation of Industry 4.0 technology. ND reports its progress independently and actively participates in the SINDI4.0 community established by the Ministry of Industry. ND also receives invitations to meetings, conferences, and exhibitions held annually. In 2020, ND received the INDI4.0 Award as an appreciation and recognition for the progress in implementing Industry 4.0.

However, I don't consider this award as an assistance since we put in all the effort ourselves.

There is additional information. Besides being a training recipient, ND is also actively involved as a training and internship provider in the government programs, such as in the Ministry of Education and Culture's Merdeka Belajar - Kampus Merdeka program. One of the shared topics is about "Digitalization" and "Sustainable Business." These ND's active involvement are forms of good collaboration with the government, leading to the government’s offers of training opportunities to ND.

That's all, Git. Feel free to ask if you have more questions now or later. If your thesis is completed, can you share it? I'd love to read it, Git :)

Best regards,

FDT

A.6. 1st Interview of Instant Noodle Company

Interview with General Manager of Manufacturing (MGM), System Development Analyst (SDS), and Central PPIC Manager (PCM) held on 15 August 2023 05.00 – 06.31 CEST.

1. How is the supply chain process of the product working from initial stage to the final stage?

   The supply chain process starts when the sales team gives a sales plan to the PPIC team, from which specific sales programs are derived. The PPIC team then determines the buffer level for the finished goods stock based on previous information. After the amount of buffer stock is determined with consideration of SKUs and inventory holding period, SAP ERP system calculates master production schedule (MPS) and material requirements plan (MRP). Once MRP calculation is done, purchase request (PR) for raw material purchases is generated and approved by factory manager. In addition, central PPIC approval is required for this PR. Following the PR approval, this PR serves as the basis for ordering raw material purchases by the central purchasing team, seasoning factory, or head office. In addition, approval from factory manager and branch manager are required for every PPIC unit in each factor to determine or change the amount of buffer stock.

2. Is there any digitalization implemented in this step of the supply chain process? How is digitalization being implemented?

   We can monitor raw material arrival when suppliers also utilize the SAP ERP system, such as seasoning factory, packaging wrapper factory, packaging box factory. All mentioned suppliers are vendors in the same company group of the instant noodle company.

We have E-Purchase Monitoring (EPM), which is a platform for suppliers to submit delivery plans and other required documents before sending their raw materials to the factory. This system allows suppliers to check any purchase orders from the factory, while also monitoring and evaluating suppliers' delivery time of raw materials. If suppliers do not submit the required delivery documents, the raw material arrival cannot be registered as goods received (GR) in the SAP ERP system. The platform includes a quality feature that sets a time limit for goods received based on raw material's production date. If the date exceeds the time limit, the raw materials cannot be registered in the system. In case of exceptions and urgency to deliver raw materials, the raw material's purchase order must be approved by central quality control (CQC) team. The approval is specific to the requested purchase order and the PPIC & QC unit in the factory will be notified regarding the issue through email. EPM also facilitates purchase rescheduling, delays, and order diversion for non-group third-party vendors, while SAP facilitates the same needs for vendors within the same company group.

Another example of digitalization is the truck queueing system (TQS) which monitors the movement of trucks delivering raw materials and their movement in the factory. The monitoring starts from entering factory area, reporting to security team, undergoing quality control checks, unloading materials, registering raw materials as goods received in SAP ERP system, and exiting factory area. This queueing system is also applied to finished goods delivery to distributors, starts from entering factory area with empty load, reporting to security team, loading finished goods, and exiting factory area. TQS also facilitates vendors within the same company group in monitoring their trucks' movement within the factory plant from entering until exiting the plant. In addition, we can prioritize unloading for trucks that deliver urgent raw materials for production. Therefore, the benefits of TQS enable vendors to monitor the trucks movement and inform the vendors regarding their trucks' position.

Implementation of e-purchase and truck queue system adopts an incremental approach during execution, considering required collaboration with suppliers. For instance, the integration of halal system is executed after feature of time limit for goods received is installed. Next, we installed the feature of manufacturing date warning to alert suppliers about material expiration. These mentioned features are integrated into each other and ensure that if any of these required conditions is not met, a purchase order cannot be generated. Over 4 years of EPM implementation, we have added more features gradually. EPM is also integrated with TQS. TQS provides GPS position of trucks, even though not all suppliers have position data available. Both mentioned systems are integrated with weighbridge, allowing to check raw materials' weight and automatically register the raw materials as goods received in SAP ERP system (depending on the type of raw materials, as not all require weighing).

3. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?

   One of the obstacles is changing user habit from paper-based process to digital approach which is data entry into a monitored and integrated system. Another obstacle is variations in human resources skills and capabilities across factories. Given the company has 17 factories, execution of a pilot project in a factory is crucial to ensure the successful implementation of digitalization. Besides, evaluation during the implementation process is important as well as training in each factory to share knowledge about digitalization. In addition to training, the central PPIC team creates a manual book to guide the execution of PPIC activities using SAP ERP system.

4. What and how are the factors that lead to the successful implementation of this digitalization?

   To ensure successful implementation of digitalization, convincing users is crucial, emphasizing that digitalization aims to improve efficiency and work effectiveness, and help monitoring of actual operations in the shop floor. To do this, the system team conducts training, showing the users the integration of the new digital system and helping actual operations in the shop floor and its monitoring tasks. By implementing the digitalization, communication between departments, internal parts of factory, such as PPIC, warehouse, QC and security, is improved because all arriving raw materials are monitored and controlled by security team (admitting arriving trucks), QC team (checking delivered raw materials, warehouse team (receiving the raw materials), and PPIC (using those raw materials for production).

5. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?

   Digitalization yields several positive impacts. Reduction in paper usage is evident in purchase order management, as orders from vendors within the company group are directly managed in the SAP system. Meanwhile, suppliers outside the company group also do not need to print purchase orders as the orders are managed in EPM platform. Before the implementation, suppliers used physical documents containing purchase order tabulation, causing wrong delivery due to errors in reading the tabulation. By using this platform, suppliers only execute purchase orders shown in the system.

TQS has positively impacted efficiency, enabling real-time monitoring through mobile devices. TQS's integration with EPM and SAP ERP system enables non-group vendors to monitor their trucks' reporting to the factory's security. It also eliminates the issue where truck drivers hesitate to enter the factory due to congestion in the factory or remain parked to have rest after completing goods issue procedures when delivering finished goods.

The automatic report generation by system and its automatic sending by email has eliminated data extraction and analysis routine tasks. This innovation also enhances meeting effectiveness, ensuring the same data among 17 factories, and streamlining coordination in weekly meetings for production coordination with seasoning factory and wrapper factory.

There is also a feature of digital approval for exceeded time limits on raw material usage in production processes. This feature enables traceability and attachment of notes that can extract data from SAP. This eliminates manual data entry, preventing wrong input.

6. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?

   Every year, the company discusses an annual plan that emphasizes innovation and improvement of efficiency and effectiveness in that year. Each project's targets will undergo evaluation and assessment to check the requirements, costs, timelines, methods, and the responsible parties. All details, including project's short- and long-term plans are justified to get funding approval from the top management.

   We also consider the impacts of every project which is discussed in the meetings of internal manufacturing team, division head and board of directors. Once the project is approved by the key people, capital expenditure is authorized, marking a green light for execution. During the execution, progress of the project is reported periodically.

7. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?

   One unsuccessful implementation is the addition of a temperature sensor during COVID period. The challenge faced due to the need for employees to gather in a specific place for temperature check. This condition created potential risk of increasing virus transmission. In addition, longer time required for the installation and disturbance during the period led to unsuccessful execution.

8. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

   The next company's plan is to prepare for upcoming government regulations on halal transport rules, including halal certificate, halal transport and MD number. The company will anticipate this by integrating these requirements to EPM platform.

   Another plan is to develop digital approval. Currently, this feature is only available for return confirmation with suppliers. Other approval still uses fax and email. If the digital approval system is ready to be implemented, it will be integrated with EPM platform.

A.7. 2nd Interview of Instant Noodle Company

Interview with Factory Manager of Plant B (BFM) and System Development Analyst (SDS) held on 8 September 2023 04.00 – 05.35 CEST.

1. How is the supply chain process of the product working from initial stage to the final stage?

   The supply chain process begins with raw material supply planning, initiated by the marketing team's confirmation of weekly forecast (CWF). These forecasts, generated based on market condition for the next month, will be posted in SAP system and become the basis for PPIC team to run Master Production Schedule (MPS) calculations. From these calculations, the PPIC team will get Materials Requirements Planning (MRP) which describes total required raw materials based on Bill of Materials (BOM) of each product. PPIC team also adds buffer stock besides orders from marketing team to anticipate sales increment in that week.

   Once MRP is completed, purchase requisitions (PRs) are released by two parties. The first PR release is done by branch office that states the order can be processed. The second PR release is done by corporate procurement & engineering division of head office to decide the supply allocation of raw material vendors both group vendor and non-group vendor. This allocation involves several considerations, such as distance, competitive pricing, vendor availability, and long-term capacity. The key objective of these considerations is to have great efficiency.

   Once receive the purchase order, raw material vendors start producing and transporting materials to the designated factory. Truck queueing system (TQS) manages the arrival and unloading of raw materials. The TQS ensures truck details and drivers' entry matched with database using fingerprint scanners, confirming communication with vendors, security checks, and compliance with safety and halal standards. After all required checks are okay, truck can be permitted to enter. Trucks delivering flour will be directed to weighing bridge which has automatic "Good Received" registration feature to SAP system. Afterwards, Warehouse and Quality Control (QC) teams further verify and authorize the received raw materials, applying fingerprint scanning at each checkpoint. Besides this process, fingerprint scanning is also applied in previous checking processes to record the execution time and the executor of authority. These checks are applied to all raw materials, such as flour, frying oil, seasonings, etc. Once the requirements are ensured, a release document for the raw material will be discharged and raw materials are stored in the warehouse.

Before starting the production process, the PPIC team plans the daily production schedule in SAP system according to orders from the marketing team. Raw material needs will be automatically calculated according to BOM of the products to fulfil the daily production schedule needs. This information regarding raw material needs will be forwarded to the warehouse team to make the warehouse team send raw materials to the production team. The production team then starts the production. After production finishes, production results will be stored in the finished goods warehouse.

After finished goods are stored in the FG warehouse, the marketing team will send delivery orders to deliver finished goods to specific destinations. This delivery order will be registered in the TQS system. In addition, details of trucks and drivers should be registered in the system to apply the food defense concept. When finished goods are loaded to trucks by the warehouse team, "Good Issued" status is recorded in SAP system as products are moved from warehouse to trucks. Outgoing quality control ensures cleanliness of trucks before exit the factory, following the queue established by TQS

2. Is there any digitalization implemented in this step of the supply chain process? How is digitalization being implemented?

   EPM is one of the digitalization that has notably streamlined connections with non-group vendors, enabling tracking of goods movement and delivery statuses. EPM is also utilized by factories to check the arrival of the delivered goods. Non-group vendors that do not deliver goods without registering in EPM, cannot register their goods as "Goods Received" in SAP system, fostering disciplined data input for the non-group vendors.

   Integration is also implemented between TQS, SAP ERP system, and EPM. TQS facilitates entry for trucks' drivers with fingerprint verification, ensuring everyone who enters the factory is registered in database. The weighing bridge has automatic "Goods Received" registration feature in the SAP system for raw materials requiring weigh processes. Auto-release Quality Control

(QC) feature authorized by fingerprint of QC team facilitates automatic release registration in SAP system. SAP ERP system serves various transactions, including raw material transfers from raw material warehouse to production and production schedule planning by the PPIC team. In addition to these transactions, there is an automatic "Good Issued" feature which is integrated with SAP ERP system, recording raw material usage in the production process. Moreover, the feature of automatic "Good Received" records finished goods transferred to FG warehouse. There is also automatic data recording for process parameters in the production section, replacing conventional paper-based methods with sensor-driven inputs. Data from automatic data recording is used as basis for process improvement and early warning system through statistical process control in case of issues.

Another digitalization effort is auto-generated daily reports which provides updates on stock, daily sales, raw material, and fuel stock, automating the reporting process. The report is automatically sent to managers, facilitating quick decision-making. This digital innovation employs business intelligence and the feature of automatic sending via email. Before the implementation, someone needs to do manual processing in SAP to make the report.

Besides enhancing business process operations, these digital initiatives encourage young employees to contribute to the digitalization projects according to their positions. The initiatives also prompt the IT division to enhance its capabilities.

The success of these digital initiatives is attributed to leadership and change management. For instance, the introduction of fingerprint scanning in TQS and auto-recording in the production process faced initial resistance, requiring a gradual shift in organizational habits. The change management approach involved gathering users, providing briefings, socialization, and trial phases. Leadership played a pivotal role in overcoming reluctance, seeking ways to align individuals with the new systems.

These digital initiatives cannot be successful without change management, gradual change and leadership. The change management concept involves gathering users, providing briefings, socialization, and trial phases. Gradual change is evident in the introduction of autorecording in the production process which started from trial in one production machine. Leadership plays a crucial role in overcoming reluctance to align employees with the new systems. This is evident in the first development of fingerprint scanning in TQS which faced difficulties to change organizational habit.

3. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?

In implementing the digitalization, every project should be aligned with head office's vision. For instance, pre-implementation discussion between management of plant B and head office ensured seamless execution of digitalization project, with value exceeding 10 billion IDR. Besides, concept alignment between vendors and factory is mandatory to ensure smooth translation of business processes to hardware and software configuration for the digitalization. Discussion related to adjustments and alignments between production team, engineering team, maintenance team is necessary to review updates on maintenance processes, sanitation protocols, and data interpretation due to digitalization.

It is important to note that technology can be quickly implemented while changing human behavior needs gradual approach. This is evident in addition to the SAP feature which utilizes gradual upgrade approach because it deals with human factors. In essence, the objective of implementing automation project is to ease data retrieval and operators' jobs.

4. What and how are the factors that lead to the successful implementation of this digitalization?

   Leadership is the main factor of successful digitalization implementation as he/she plays an important role in driving advancement in his/her unit. Regardless of the project's complexity, decisive leadership is crucial for overcoming challenges and ensuring smooth implementation. Besides, forming a team that has a deep understanding of the process is mandatory to ensure the successful implementation.

5. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?

   Digitalization has numerous benefits. One of them is easier operations and remote monitoring by using any internet-connected devices, eliminating the need for on-site presence to gather process parameters, and reducing the use of paper. In addition, easier observation and monitoring make easier process evaluation and faster decision making, streamlining improvement process, reducing waste, generating more production outputs.

   Digitalization has increased efficiency for operators, allowing one person to handle tasks previously managed by two machines. This happens due to human role replacement with machines or automation. Affected employees will be transferred to departments with fewer resources. This strategic human resource allocation is discussed in meetings between the head office and branch offices, promoting a balanced workforce and maintaining overall productivity.

The feature of automatic recording minimizes human errors and ensures safe storage of data on the servers, limiting access only to authorized people. Storing data on servers also enables data access from any location connected to the internet.

Regarding electricity consumption, sensors installed to machines have very low consumption and enable the team to identify areas for improvement in terms of electricity consumption.

It is true that the first investment of digitalization is substantial in money value. However, it can be anticipated by calculating the economic parameters like payback period and return on investment.

6. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?

   Factors that drive the company's digitalization come from both inside and outside the company. Internal factors are exemplified by directions from top management and challenges from the division head to branch managers to enhance productivity and efficiency. These organizational pushes are translated into technical details by subordinates. Besides, middle management is consistently pushed by themselves to become better from time to time.

   Vendors and information from technological fairs are examples of external factors that drive digitalization in the company. Sometimes, we invited competent vendors in automation to provide insights of current technology development, enabling us to know the information and align the development with our existing business processes.

7. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?

   Fortunately, there is no unsuccessful story. However, the completion time of projects varies depending on its complexity and support.

8. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

   The upcoming digitalization initiatives still have the same goals which are pursuing better cost efficiency, better production cost, and fostering more profitable conditions. These initiatives focus on developing the potential of current projects and their opportunities for future development. For instance, we are currently developing instant water content check and autofilling function for frying oil with autorecording and autotransaction to the SAP ERP system. Autofilling feature will make operations easier and eliminate manual transaction. Other ongoing projects are integration of TQS with distributors' system and the gradual GPS installation to non-group transporters' trucks, enabling delivery truck movement tracking. However, these projects will be implemented gradually, considering investment by the transporters and permission from head office.

A.8. 1st Interview of Personal and Fabric Care Company

Interview with Senior Plant IT Manager (ITP) held on 18 August 2023 09.00 – 10.31 CEST.

1. How is the supply chain process of the product working from initial stage to the final stage?

   The main supply chain activities in the company are making, packing and distribution/shipping. Raw materials, such as packaging, cardboard, plastic wrappers, and chemical base ingredients, follow just-in-time (JIT) to minimize inventory cost. Prior to storing in the warehouse, incoming raw materials are checked to verify their quality, specifications, and halal certification, especially for materials sourced internationally. Some liquid raw materials are directed immediately to machines lines, while others are stored in the warehouse before being moved to the making area.

   The making area only involves the production process as product content will be temporarily stored in withholding tanks before being transferred to the packing area. In the making area, there are production lines for shampoo (hair care) and fabric enhancer which have different production systems due to differences in their nature of processing. Hair care products employ a batch production system which has smaller area, while fabric enhancer is continuous and highly automated which has 60% of soccer field area size. The hair care production line is set manually and needs 6 persons in a shift, while the fabric enhancer production line is controlled by 2 – 4 persons in a shift using human machine interface (HMI) which can directly push product formula settings and parameters to machine lines. When the packing system is ready, product content will be streamed from withholding tanks to the packing area.

   In the packing area, the packing lines are not differentiated by products for hair care products. These lines are equipped with various machines to accommodate different packaging forms, such as sachets and bottles. Each packing machine requires 3-4 personnel per shift, totaling 15-20 persons for one packing area. The end-of-line area, part of the packing area, involves contractor workers preparing cardboard boxes on palettes. However, these contractors are prohibited to involve in core processes like making and packing, even in the cleaning tasks due to the high standards required and company policy.

After the end-of-line process, finished goods are transferred to the distribution center (DC), which co-located with the plant. In DC operations, 20% of operations are handled by autonomous intelligent vehicles. The DC, in addition to storing finished goods from the plant, handles other company's products from various sources, including imported products and contract manufacturer's products. The distribution of these products is managed by distributors. In several cases, the company directly sells products modern retail groups in Indonesia, while also exports to other countries like Thailand, the Philippines, and Australia, complying to each country's specific standards and requirements.

2. Is there any digitalization implemented in this step of the supply chain process? How is digitalization being implemented?

We have done many digital initiatives along the supply chain. We implemented a material certification upload platform where suppliers upload material certifications, eliminating individual certification checks. We also assisted raw material suppliers to implement process control strategy (PCS) which ensures controls over production parameters. If production parameters are okay, the production will yield good products. The PCS leverages Power BI and a simple database system and has significantly improved the quality of critical raw materials, leading to waste reduction and better quality of production outputs.

In the warehouse, we are currently implementing warehouse management system (WMS) which has feature to effectively assign nearby picking workers to gather items to the collection point, improving productivity of warehouse workers. In the security domain, we use Excel and PowerBI for monitoring suppliers' trucks that enter the plant area. This system collects data, including trucks' position in the plant, its current process, license plate, drivers' identity, supplier details, and its supplied goods. This digital approach replaces previous verbal coordination, providing visibility of trucks' movements and aligning with the company's security policy of limiting supplier truck presence to 24 hours.

In the making process, industrial automation is integrated, capturing all data from machines using sensors for process control. The company utilized Purdue Model concept to implement the industrial automation. The concept has four levels as below:

- 0th level which is sensing and actuator layer,

- controls layer on the 1st level (contains PLC controlling motors and sensors),
- supervisory on the 2nd level (contains HMI controlling PLC from the interface and showing process parameters and process flow diagram (PFD) of the whole process),
- manufacturing execution system (MES) on the 3rd level, showing daily production plans, current running machines, machines' downtime and downtime's reasons (by root cause analysis). Personnels are able to input downtime's reasons, enabling two-way communication.
- corporate ERP level on the 4th level, considering all business function and it is the backbone of the company. Currently, conversion to cloud version of SAP ERP system is ongoing.

In making and packing areas, almost all motors and sensors are connected to PLC, enabling data capture by connecting PLCs to consoles or using Historian software for continuous process. This connected system enables pushing formula to machine lines, allowing PLC to adjust the machines according to the requirements. Benefits of each level of Purdue Model are:

1. Level 1: enabling control of all machines (one PLC can control more than one machine). The previous version of PLC is only able to control 3-4 machines while the current version of PLC can handle 12 machines at a time.
2. Level 2: improving productivity. For instance, previously it needed many personnels to handle one line of machines, while after the implementation, it only needs 2-3 personnels to control one machine line by using HMI.
3. Level 3: simplifying management and enhancing productivity. Before implementation, we needed to take data manually in case of breakdown. After implementation, all data regarding breakdown reasons are shown in the HMI. In addition, it also simplifies production execution. Before implementation, we needed to download data from SAP regarding production order and its materials' readiness. After implementation, all data is shown in the MES interface. Operators only open MES to know daily production plan without any need to open other software.
4. Level 4: there is corporate data lake at this level to aggregate all data from SAP, and MES. This data can be used for analytics. For instance, this data is harnessed to generate savings in water, air, gas, electricity, steam (WAGES) / utility area. Collaborating with analytics vendor, we applied machine learning to gain broad insights. This system also improves reporting work as we use PowerBI to seamlessly connect corporate data lake to make reports. This eliminates tedious work of data extraction from

SAP, ETL using Excel, and analysis process. In addition, manual calculation of reliability is removed since Proficy implementation.

Currently we are working on two projects in the packing area, focusing on a machine with multiple motor servos that frequently experiences breakdowns. We do not have sufficient data and insights to identify the cause of the breakdown and predict the occurrence. The 1st project is focused to track historical discrete data, which is complicated by the nature of the data, making it challenging to track historically. To address this, we developed an in-house application to manage history data of packing area, historize all defined PLC tags, and build machine learning models using the data. Additionally, we collaborate with a vendor employing sensors to measure temperature and magnetic flux on motor servos by sticking them outside the motor. These sensors, utilizing low range wireless access network (LoRaWAN) technology, transmit data to the plant network and the vendor's machine learning server for data analysis.

In the warehouse, we also implement Autonomous Intelligent Vehicle (AIV) which is touchless. Unlike Automated Guided Vehicles (AGV), which rely on floor markings, AIV harnesses wireless technology for routing. Besides, AIV has faster and more integrated processes as it operates on Linux.

In our material testing laboratory and quality team operations, we utilize Nexus LIMS, a web- based application of laboratory information management system. This system can establish workflow for each sample test, assign tasks to personnel, and allow various laboratory equipment brands to seamlessly record and send test data to the LIMS server. This application improves data flow and integrity, eliminating errors in previous paper-based processes.

Another example of our digitalization is exploiting the use of Python. Our technicians leverage Python to make robotic process automation (RPA) that automates the web form-filling process, overcoming big effort to manually fill the forms. This use of Python is one of company's agile mindset example in encouraging incremental innovation. We also use this Python-based RPA to automate registration of "Goods Received" and "Goods Issue" in SAP ERP system from Historian software related to actual material consumption, eliminating individual checking and input of numbers to the system. This innovative use of Python bypasses the company's strict policy of non-standard applications by addressing specific pain points without compromising on the compliance.

3. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?

   Obstacles in digitalization implementation are centered around human behavior, legacy, and funding. Human behavior encompasses maintaining and ensuring successful implementation of digitalization which needs leadership in its process. Legacy involves infrastructure, work process, and documentation in the system which can be influenced by digitalization, either addition or reduction in system's features. For example, implementation of Purdue Model's industrial automation removed a form application due to interconnectivity between tools after the implementation which can do the same task. Funding issues also arise from the company's portfolio, where top management usually suggests applications already implemented in other plants without considering labor costs and budgets. For instance, we opted to use Python-based RPA over BluePrism which has higher cost because lower labor costs make the BluePrism implementation in developing countries have no return on investment.

To address challenges in human behavior and legacy, leadership holds an important role. Leaders must use their authority to enforce digital implementation usage in operations teams, underlining the benefits and justifications for digital tools adoption. Moreover, the digital team should act as a voice of reason, underscoring necessities of digital implementation and relating it to everyday tasks, particularly in reducing manpower through manpower transfer to optimize operational efficiency.

4. What and how are the factors that lead to the successful implementation of this digitalization?

   Besides leadership, compliance with established rules is one of key success factors in digitalization journey. The company applies strict IT governance, requiring every device, application, and software to undergo registration and assessment process before being implemented in the company. Justification of the application needs to be provided to prevent installation of redundant or obsolete applications, incurring unnecessary maintenance costs. For instance, installing sensors with LoRaWAN technology needs examination of the device and its manufacturer while fulfills specific Wi-Fi technology requirements. Another example was the rejection of Foxit PDF Reader due to Adobe PDF Reader existing subscription, extending the complication to the utilization of free software. It is worth noting that value protection is as important as value creation, underscoring synergy between these aspects.

5. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?

   Reduction in paper usage and waste are the most obvious benefits. Digitalization enhances efficiency of business processes, increasing material utilization and reducing electricity consumption. This helps use in fulfilling KPI of material utilization around 99%, indicating minimal waste generation.

Despite very little waste, this waste is responsibly sold to third-party vendors for treatment, ensuring more sustainable production processes. In terms of leaner electricity consumption, this can be achieved using analytics in WAGES / utility area, improving our heat exchanger, and decreasing WAGES cost and waste.

In terms of social impacts, digitalization increases productivity by reducing human resources due to more efficient work. In addition, our employees have better well-being, shown by more ideas generated due to more free time as menial works are replaced with automation. During their free time, employees explore ways to improve their work, which the company's digital team actively supports. Beyond the organization, digitalization gives positive effects to the community as we helped our suppliers to improve their materials using PCS. We also help distributors to manage their ERP systems, transferring new capabilities to domestic companies.

However, it is important to note that digital solution is not the solution for every problem since it depends on its value creation by considering its costs and benefits.

Fortunately, we have no story related to the increase in electricity consumption due to digitalization. Furthermore, the human resources reduction issue has been addressed by the company by maintaining a policy of permanent employment for all employees. The company also has a technician work system that manages the versatile skill set of technicians, allowing flexible transfer between departments.

As the company enforces strict IT governance, there is no story related to information leaks. In addition to governance, we ensure that all assets are assessed before installation and implementation of confidential disclosure agreement (CDA) with suppliers, combined with training and infrastructure assessment.

6. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?

   To drive implementation, the company sets vision and strategy for digitalization, aligning with goal of value creation. We recognize that digitalization creates value, leading to investment grade and opportunities for increased sales volume, export quotas, and establishment of new business units. Opening new business units means increasing employment and generating a new market for domestic suppliers. We also try to drive seamless flow from suppliers to customers by optimizing manufacturing process and installing AIV for seamless distribution.

In addition, the company embraces employees to explore and learn by giving reward and recognition for innovative ideas, not solely limited to digital solutions. Besides, ideas from soft floor employees push the digital implementation by having daily stand-up meetings for addressing issues in the operations and brainstorming.

From the external sides, competitors indirectly serve as our motivator for continuous improvement. Additionally, insights from management, derived from external sources, are cascaded down to lower company levels. In our case, the government does not give support in our digitalization journey. However, we collaborate with suppliers in their PCS implementation. Meanwhile, customers indirectly influence through product defect complaints, such as missing code data.

7. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?

   There were some challenges during the digital implementation, such as unclean data, bad UI/UX which complicates the software utilization. Insufficient funding and conflicts with the existing digital portfolio also contributed to unsuccessful implementation. For instance, proposals of creating new applications are rejected due to duplication with functions of existing applications.

8. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

   Our next digital initiatives include the implementation of digital twin to double our current capacity of machines, simulating real conditions to enhance productivity and potentially sell the machines to other plants. This allows us to have less capital and less depreciation in our production processes. Another project is achieving 100% digitally controlled sample, providing quality assurance to DC. Currently, the plant team pays quality assurance money to DC in reverse to percentage of checked product samples, verifying the filled weight of the products. By checking every sample, the plant team can avoid paying assurance money to DC, leading to cost savings.

   In addition, we continuously develop improvements in WAGES / utility area to drive savings in that area. Moreover, we integrate upskilling programs to our work system as a part of promotion and employees' career progression.

A.9. 2nd Interview of Personal and Fabric Care Company

Interview with IT Distributor Operation Manager (coded as ITD) held on 20 August 2023 10.00 – 11.49 CEST.

1. How is the supply chain process of the product working from initial stage to the final stage?

   The supply chain process from raw material sourcing to finished goods storing in distribution center (DC) is managed by ITP, while I manage distribution process of the distribution center. Process managed by ITP is called backend process, while my process is named frontend process. To manage supply and demand in distribution, we have a forecasting system to bridge DC and sales department, preventing condition of increasing non-productive inventory (condition of high supply and low demand) and out of stock (condition of low supply and high demand).

   Distributors place orders for finished goods daily and handle the general trade market, regional modern retailers, and small medium enterprise (SME) stores. The procedure of product distribution can be explained as follows. For instance, distributors place orders today which are processed by DC at night on the same day. These orders are delivered in the morning of the next day and distributed to the stores in the afternoon. These orders are ready in the stores by the second day after the placement of the orders. However, stores can ask for the orders to be delivered on any other day more than 2 days. These delivered goods are then invoiced, with any unavailable items noted in the invoice. Upon goods arrival, distributors register the items in their warehouse system. The previous instance is valid for deliveries within Java Island. For areas outside Java Island, the process can take up to two weeks due to longer delivery times from the company's DC to distributors' warehouse / DC. This condition makes out-of-stock occurrences for outside Java Island.

   In the case of modern trade market distribution, the company directly handles the sales as national modern retailers directly pull stocks from the company's DC. In the case of e-commerce distribution, there is only one e-commerce DC, and the orders are handled by distributors in partnership with the company, including orders from e-commerce platforms like Shopee and Tokopedia. The amount of ready stock products is kept in the DC based on historical sales record.

2. Is there any digitalization implemented in this step of the supply chain process? How is digitalization being implemented?

   There are several digital initiatives in the company. We have tracking planning system to assess if the distributor's DC stock can meet all customer orders with high fulfillment rate (>90% orders can be served). The system employs plan-do-check-act principle and leverages distributors' daily updated data of product stock level, enabling daily check and action following unfulfilled SKU orders. In addition, this system utilizes a specific dashboard that can notify users of potentially unfulfilled SKUs and its amount for fulfillment prioritization. Blockchain is not utilized in this system due to its high implementation costs.

Another example of our digital initiatives is the warehouse management system (WMS) integrated with transportation management system named dynamic routing system (DRS) and distributors' ERP systems. WMS is not only able to manage warehousing system, but also capturing non-performing inventory (NPI). This enables us to immediately respond the logistics issues. The DRS enables us to optimize daily delivery routes for trucks using machine learning algorithms and collaboration with a third-party contractor. In addition to machine learning algorithms, this system harnesses data, alert system, and dashboard. The objective of the system is to reduce costs by calculating the required number of trucks, considering ownership by the company, distributors, or rental companies. We also consider Volume Filled Rate (VFR) as key performance indicator, indicating the percentage of products' volume that can fill truck's capacity. Both the number of trucks and VFR are controlled to ensure sustainable operations and costs because excessive load of trucks may cause longer delivery and loading time and higher maintenance cost due to more frequent spare part replacements. Consequently, the integration between WMS, DRS, and distributors' ERP systems aims to create one data operation in the supply chain.

3. What are the obstacles in the digitalization implementation? How are the obstacles being tackled?

   In addressing the challenges during digitalization journey, the company harnesses plan-do-check-act principle, starting from planning the targets, checking the actual execution, running the system, checking the results, and organizing next steps if there is an issue.

   During the implementation of DRS, there were several challenges both internally and externally. Internal challenges involved adoption issues among delivery personnel, such as wrong clicks and reluctance to use the apps which can be tackled in the first 2 months. Integration with distributors' systems also faced challenges due to multiple data sources and different ERP systems used by the distributors, requiring fine tuning with those different ERP systems. Convincing distributors to adopt the system and demonstrating that the company's solution provides more value than current processes is crucial. More value does not only mean cost reduction, but also fixed cost cut in transportation fleet. Meanwhile, external challenge involves landscape and geographic challenges, such as traffic regulations and harsh terrain between places in Indonesia, adding complexity in the implementation.

To overcome mentioned challenges in DRS implementation, the company employs hypercare approach during the first 2 weeks to 1 month, requiring immerse observations like following the users' activities to know the actual process, simultaneous running with existing solution, and fine tuning of the application. The objective of hypercare is to identify necessary adjustments of the application. In addition to convincing the distributors, we set specific targets with the distributors, such as an increase in VFR and cost reduction to evaluate the solution's effectiveness. We also utilize hypercare approach in the implementation with distributors. Since the biggest challenge is how to sell the digital solution to the distributors, we involve multifunctional teams, such as finance, sales, logistics, IT, HR to make distributors see holistic view of the digital solution.

In the context of WMS implementation, the challenge is selling the digital solution to distributors and dividing tasks and responsibilities between the company and the distributors. To address this, both distributors and the company plan together the project's targets, scope of work, and each parties' responsibilities. Discussion with vendors on solution blueprints and win-win solutions between vendors, the company, and distributors is done to ensure well-coordinated efforts. Another emerging issue is introduction of new business process after digital initiatives implementation since the users were accustomed to paper-based processes. Ensuring the right output data of the new solution is another challenge, particularly identifying wrong input in users' first usage.

4. What and how are the factors that lead to the successful implementation of this digitalization?

   According to our experience, the planning process plays a critical role as the right planning constitutes 70% of the entire work. During the planning stage, roles and responsibilities are set. Setting achievable targets and its value creation are also important factors as some failed projects happen due to unattainable targets. In every project, we set cost reduction as the parameters.

5. How has digitalization positively and negatively impacted the process sustainability in terms of social, environmental, and economic aspects? Regarding the negative impact, how does the company anticipate the impact?

   Digitalization has brought both benefits and drawbacks to our operations. Economically, cost saving is our main objective in implementing digitalization which has immediate effect. By optimizing costs, we can reduce capacity, which has both positive and negative impacts. For instance, WMS implementation reduces previous manual tasks, increasing productivity due to job automation. However, capacity reduction also means reduction in human resources, such as 1 person can do more than 2 jobs. There is also concern about high implementation costs, comprising operational cost and one-time cost. Operational costs can range between 50 – 100 million IDR while one-time cost ranges between 500 – 600 million IDR. The substantial value of one-time costs are related to cost of development, , fine tuning, and addition of administrator for first 3 or 4 months. To overcome the one-time costs, we utilize savings from the first years of implementation, as a part of the cost planning strategy we did prior to implementation.

Environmentally, digitalization reduces paper usage which is part of paperless operations campaign by the company and distributors. This also eliminates the risk of data loss due to paper records and reduces paper costs which can cost 70-100 million IDR. However, there is also negative impact caused by integration between WMS and TMS which is increasing delivery fleet and NPI. This causes an increase in fuel costs and pollution. It is important to note that this integration's negative impact happened only in the first months after the installation and adjustment of tools. The same issue also happened in the first implementation of forecasting system which increased NPI related to damaged return or expired product. These NPI products should be burnt according to government regulation, affecting negatively to the environment.

In the context of operations, digital implementation introduces real-time data access, influenced by digital initiatives, such as forecasting system, integration between systems, and tracker system. Before digital implementation, manual recap of data was retrieved on weekly basis, even bi-weekly basis. Integration between WMS, DRS, and distributors' ERP systems enables better forecasting, and a more responsive tracker system due to daily updated data. In addition, these digital initiatives do not impact increasing electricity consumption.

6. What are the internal and external factors that drive the implementation of this digitalization? How does the factor push the digitalization implementation?

   There are factors that drive during the company's digitalization journey both internally and externally. Internally, top management holds an annual meeting that discusses prioritization of digitalization plan and evaluation of currently running projects. This prioritization follows top-down management approach, with directives form the regional office of the company, cascading down to the company's Indonesian management. In addition, the company embraces collaboration through sharing sessions between regional plants. The Indonesian office is included in in Asia, Middle East, Africa (AMA) region of the company. In the sharing session, we discuss issues and ways to solve them. If there is any solution from other countries in the regional team which fits our problems, we solve with that way. However, if there is no solution from regional team, we seek the problem solving by ourselves.

In the context of external factors, the customer indirectly influences the journey, such as the need for faster delivery than 2 days. We also do monthly evaluation with distributors regarding our partnership. In addition, competitors indirectly influence the company in terms of delivery service times, as the company's supply chain has a different approach due to the difference in the numbers of distributors. The company has less than 10 distributors all over Indonesia, while the competitors like UR and WS has more than 20 distributors. The government is also involved in the company's digitalization journey despite not directly related to digitalization. The recent event related to government involvement was the cough syrup drug sales ban, causing 2 months stop of drug sales and increased NPI of the drug.

7. Is there any unsuccessful implementation of digitalization in this step of supply chain process? What are the factors that make the implementation unsuccessful?

   In general, we do not have any unsuccessful digital implementation. However, geographical conditions and uneven infrastructure in different regions of Indonesia are notable challenges during the implementation. These challenges impact distributors' infrastructures, escalating the implementation cost. Data reliability is also noted as one of the challenges, as data is abundant but not easily captured.

8. What is the next plan of digitalization in this step of supply chain process? How will digitalization impact the process in terms of social, environmental, and economic aspects of sustainability?

   Our forthcoming plan in the supply chain is updating our supply network design that is revised every five years. This update is necessary to fine tune and adjust with the new digital solution, such as cost calculation automation to leverage high availability of current data. This update also improves our capacity in terms of people's capacity reduction and cost savings, leveraging the ongoing infrastructure development in Indonesia.

A.10. List of Codes in the Verbatims

AE	Competitor of Ice Cream Company
AMS	Colleague of OAM
B-Apps	Apps made by global HQ of WL
BPOM	Indonesian National Agency of Drug and Food Control
BV	Bureau Veritas
CAPEX	Capital Expenditure
CEO	CEO of Powdered Beverage Company
CL	Former Colleague of Author
DTM	Digital Transformation Manager of Powdered Beverage Company
DTP	Digital Transformation Project Manager of Powdered Beverage Company
DY	Product of Personal and Fabric Care Company
EMC	Engineering Manager of Plant S in Powdered Beverage Company
EMK	Engineering Manager of Plant C in Powdered Beverage Company
FI	Country Manager of Schneider Electric Indonesia
GE	General Electric company
GI	Product of Personal and Fabric Care Company
GMP	Good Manufacturing Practice
GO	Competitor of Ice Cream Company

GR	Good Received status in SAP ERP system
HDT	Head of Digital Transformation in Powdered Beverage Company
HHR	Head of HR in Powdered Beverage Company
HND	Head of Division Instant Noodle Company
HRD	HR officer of Instant Noodle Company
HS	Product of Personal and Fabric Care Company
IaaS	Infrastructure as a Service
ID	Instant Noodle Company
IE	Product of Instant Noodle Company
IO	Subsidiary of ID
IP	Subsidiary of ID
K3L	Health Safety Environment
KPI	Key Performance Indicator
KT	Former Colleague of Author
LB	Other product of UR
ManEx	Manufacturing Excellence
MI	Former Colleague of Author
MK	Partner of Personal and Fabric Care Company
MN	Product of Ice Cream Company
ND	Powdered Beverage Company
NI	Product of Powdered Beverage

	Company
NIA	Sub-product of Powdered Beverage Company
OAM	Assistant Engineering Manager for PM Excellence & OEE Improvement of Ice Cream Company
OCR	Optical Character Recognition
PE	Product of Personal and Fabric Care Company
PO	Purchasing Order
PP	Product of Ice Cream Company
PR	Personal and Fabric Care Company
PTW	Permit to Work
QC	Quality Control
RE	Product of Personal and Fabric Care Company
RMS	Raw Material Storage
RX	Other product of UR
SaaS	Software as a Service
SBO	Former safety application in WL
SEA	Southeast Asia
SI	Product of Instant Noodle Company
SKU	Stock Keeping Unit
SMS-D	New smart manufacturing system
	of WL
SMS-I	Smart manufacturing system in powdered beverage company
SMS-P	Current smart manufacturing system of WL
SMS-PL	Smart manufacturing system in powdered beverage company
SN	Product of Personal and Fabric Care Company
SOP	Standard Operational Procedure
SPC	Statistical Process Control
TBB	Tea-based beverage
Tbk	Listed companies
UR	Parent company of the Ice Cream Company
VS	Product of Personal and Fabric Care Company
WAGES	Water, Air, Gas, Electricity, Steam / Utility area
WL	Ice Cream Company
WS	Competitor of Ice Cream Company

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