International Journal of Technology 15(4) 1071-1087 (2024)
Received September 2023 / Revised February 2024 / Accepted February 2024

International Journal of Technology

http://ijtech.eng.ui.ac.id

Transforming Agricultural Supply Chain Challenges into Operational Strategies: Insights from an Agri-Machinery Company

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Abstract. The paper proposes a process to translate systemic grand challenges of agricultural supply chain into company specific operationalization actions. The objectives of this study are to elucidate the requisite stages of the process, delineate the specific aspects addressed by each step, and present potential methodologies employed throughout the process. The approach adopted in this paper is inherently constructive, employing a mixed methodology that integrates various methods and tools. Furthermore, 90 challenges of agricultural supply chain are delineated and structured around 6 themes. The strength of evidence of the challenges is then analyzed with a model that takes into account the number and types of references in which the challenges are mentioned and found, respectively. The study identified 21 challenges as "evident" and proceeded to the next step for quality function deployment. Finally, operationalization actions, including cooperating with other stakeholders of the supply chain, regulators, and farmers were determined to tackle critical first mile challenges for the case company. The paper makes a distinctive contribution by presenting a comprehensive framework for translating systemic agricultural supply chain challenges into actionable steps, uniquely addressing the intersection of intricate challenges and sustainability imperatives. This novel approach does not only advance the understanding of operationalization but also underscores the vital role of sustainability in navigating the complexities of modern agricultural supply chains.

Keywords: Agriculture; First mile; Supply Chain; Sustainability; Quality function deployment

1. Introduction

Climate change, biodiversity loss, deforestation, agricultural land degradation, and declining soil quality due to compaction are significant challenges to major production systems (Hussain *et al.*, 2023; Karasu, Hussain, and Leviäkangas, 2023a; FAO, 2017). These challenges affect various stages of the agricultural supply chain (ASC), with inefficiencies leading to the global loss of one-third of agricultural produce, mainly at the first and last mile stages (Porter and Reay, 2016; Cuéllar and Webber, 2010).

Despite the pivotal influence of first mile activities on subsequent ASC stages, research into agricultural logistics predominantly concentrates on the last mile ASC (Karasu, Hussain, and Leviäkangas, 2023a; Lingjuan, Linhong, and Menghan, 2018). Therefore, this study, aims to determine the challenges encountered in the first mile of ASC. Dasgupta,

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doi: 10.14716/ijtech.v15i4.6635

Kanchan, and Kundu (2019) defined first mile as "essentially the leg of fulfillment cycle where products are picked up from sellers and are connected to the sortation centers to facilitate the further downstream connections to deliver the product on time to the customers." The challenges are vast and mostly responded in an incremental manner, i.e., solving only one or few problems at a time instead of one-time systemic, or radical innovations.

The corporate sector played a crucial role in addressing these challenges, aiming to ensure that products and services contributed positively to the solution rather than worsening the issues (Karasu *et al.*, 2023b). However, corporations often face limitations in introducing systemic solutions due to existing standards, regulations, and market structures governing diverse operations (Khoirunisa, Mushfiroh, and Gamal, 2023). Despite these constraints, many companies focused on innovating new products that offered solutions to current and anticipated challenges. The innovations typically aim to reduce environmental impact, such as carbon footprint, through strategic choices in materials, supply chain (SC), and product lifecycle management, including energy consumption.

The European Union (EU) acknowledged the significant role of the corporate sector in transitioning to a green economy, as proven by the Green Deal initiative (European Environment Agency, 2019). This initiative was implemented through various funding programs, including the New European Bauhaus concept, which offered grants and loans to promote sustainable practices among companies. The EU Green Deal Industrial Plan (European Commission, 2023) outlined strategies to facilitate the transition, namely simplifying regulations, enhancing access to funding, and developing skills. Simultaneously, EU regulations, such as European climate law, mandated significant reductions in greenhouse gas emissions, compelling industries to adopt sustainable practices (European Union, 2021). These regulations are in line with global initiatives, namely the Paris Agreement and the United Nations 2030 Agenda for Sustainable Development, which centered on a bottom-up approach, where countries identify priorities and adopted specific actions accordingly (Dzebo *et al.*, 2019).

The translation of the challenges into actionable steps remained unclear due to competitive pressures which focused on meeting customer requirements rather than addressing broader challenges. Several existing labeling and certification systems, such as International Organization for Standardization (ISO) standards, namely ISO 14025, ISO 1406, and ISO 14027, often lack transparency. These systems often assess a limited scope of parameters, raising concerns among organizations, including the European Consumer Organisation (2022). Therefore, there is a critical need for robust scientific evidence that is reliable, transparent, and valid to inform sustainable practices effectively.

Translating enormous challenges into operationalization actions (OAs) poses a complex task (Sharma, Mehta, and Sharma, 2010). This causes companies to consider two methods, namely top-down, ensuring challenges are in line with customer needs, and bottom-up, understanding the product impacts (Puglieri *et al.*, 2020; Zhang *et al.*, 2019; Shen, Tan, and Xie, 2000). Despite sustainability becoming a persuasive factor for companies, literature on responding to these challenges is scarce. Intergovernmental organizations focus on strategic initiatives, such as the efforts of the World Economic Forum to promote manufacturing resilience (World Economic Forum, 2023). While tools such as the OECD Sustainable Manufacturing Toolkit provided indicators for environmental performance, it lacked comprehensive guidance on achieving desired outcomes (OECD, 2011).

In recent agricultural logistics research, technology adoption and sustainability have gained significant attention (Abdullahi *et al.*, 2024; Jianying *et al.*, 2021). The focus had predominantly centered on the downstream level or the entirety of the ASC rather than the upstream counterpart (Heryani *et al.*, 2022; Naseer *et al.*, 2019). There are limited preliminary research on the upstream level, particularly the first mile stage of ASC (Dasgupta, Kanchan, and Kundu, 2019). Lingjuan, Linhong, and Menghan (2018) conducted exceptional seminal research, aiming to optimize the first mile of ASC through the development of a network platform. However, there was a significant gap in the literature concerning the operationalization of systemic challenges at the company level. This research proposed a method to translate systemic challenges into company and product-specific OAs. It aimed to outline the steps, address specific aspects, and explore prospective methods through an example and case study. Furthermore, the method introduced novel insights derived from the study, focusing on previously unexplored aspects and offering new perspectives on addressing systemic challenges in the ASC. The constructive method applied to increase innovations varied from the Schumpeterian model (Ziemnowicz, 2013). The proposed construct functioned as a normative process model, offering an ideal or applicable framework (Verworn and Herstatt, 2002). It was also viewed as a meta-model, comprising various distinct elements connected sequentially. In addition, a detailed proposed construct is shown in *Section 2*.

This study addressed the following research questions.

RQ1. What are the first mile challenges identified in previous research and references focusing on the agricultural supply chain, and how can these challenges be categorized into clusters?

RQ2. How can the evidence level of first mile challenges be evaluated, and what challenges are particularly evident?

RQ3. Which of the first mile challenges relate the most to the selected use case, i.e., agri-machinery case company?

RQ4. How can the first mile challenges be operationalized?

To address RQ1, this study identified and clustered first-mile ASC challenges from existing literature, as discussed in *Subsection 3.1*. For RQ2, a method to rank and prioritize the evidence of challenges was developed, as stated in *Subsection 3.2*. To address RQ3, semi-structured interviews and surveys were conducted with a company specialized in agri-machinery. The insights gathered from these interactions informed the development of the QFD framework in *Subsection 3.3*. Finally, the QFD framework was implemented in an agri-machinery company to explore RQ4, as stated in the same *subsection*. This systematic process enabled the formulation of concrete plans for agri-machinery companies to reduce first-mile challenges effectively.

2. Methods

The proposed construct described four significant steps, namely Identification (I), Structuring (S), Prioritization, and weighing (P), including Operationalization (O), collectively referred to as ISPO in separate sections of the research, as shown in Figure 1. ISPO aimed to address challenges systematically using methods and tools described in subsequent subsections. It acts as a stair-like research process, refining systemic challenges into structured solutions and operational actions, starting upstream rather than following traditional models (Reis *et al.*, 2022). Identification included a traditional literature review using specific keywords. Structuring entailed a heuristic process, establishing a hierarchical tree of significant challenges. Prioritization relied on evidence scoring reported by Stichler (2010), with the weight of challenges determined by the type and number of references addressing the issues. Operationalization adopted Quality Function Deployment (QFD), integrating actions to address ASC challenges, particularly in the first mile stage

(Wicaksono and Illés, 2022; Onar *et al.*, 2016; Zarei, Fakhrzad, and Paghaleh, 2011). The ISPO process was exemplified in the agri-machinery context as part of the LEVITOI research project funded by Business Finland and the University of Oulu (https://www.oamk.fi/en/partnership/rdi-projects/levitoi-home).

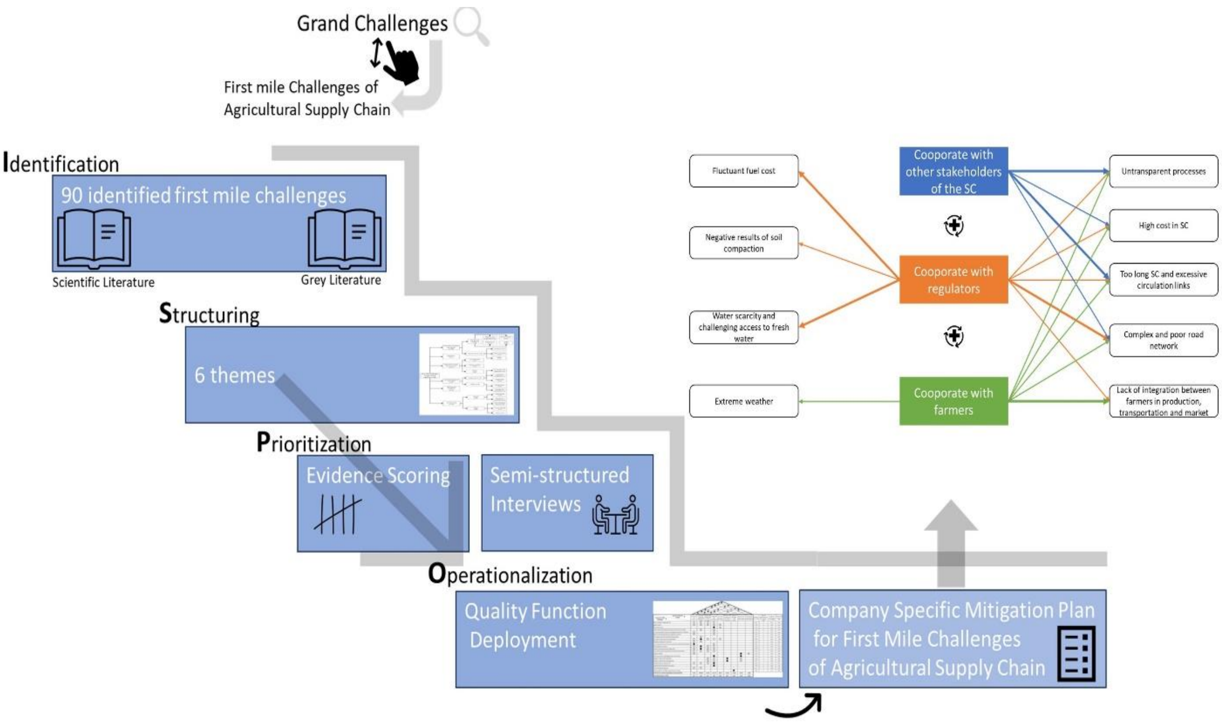


Figure 1 Overview of the research process for transforming agricultural supply chain challenges into operational strategies

2.1. *Identification and Structuring of Challenges (I and S)*

The scientific literature review protocol (Sauer and Seuring, 2023), supplemented by an analysis of grey literature was used to identify the challenges. The main search terms were formulated for scanning the selected database, Scopus. However, due to the limited use of the term first mile logistics in preliminary research, the search focused on identifying challenges associated with the first mile stage of ASC through the following string. The search was limited to the last decade, ensuring the identification of up-to-date challenges using Scopus, which was scanned by applying the following search string.

TITLE (("challenge" OR "problem") AND ("supply chain" OR "logistic") AND ("agri* ")) AND (PUBYEAR > 2011 AND PUBYEAR < 2023). Forty grey literature resources, comprising international and national reports, were added to the 46 references screened in Scopus. Based on the inclusion and exclusion criteria, the 86 resources was reduced to 66 references obtained from both scientific (29) and grey literature (37). The literature review of selected references resulted in the identification of 90 overlapping but distinct first mile challenges of ASC. These 90 challenges were initially grouped into 30 concepts and subsequently clustered around 6 distinct themes. In addition, a detailed literature review is presented in *Subsection 3.1*.

2.2. *Prioritization and Weighing of Challenges (P)*

The need to distinguish between evident and recessive challenges became apparent. The data obtained was analyzed, and references were ranked based on a six-level evidence scale, which ranged from 1 to 6 (Stichler, 2010). Level 1 comprised systematic reviews and meta-analysis of highly evident references. In addition, Level 6 consisted of stakeholder opinions, which tend to be subjective. Each of the 66 references were ranked and assigned a value between 1 and 6. The evidence score of each challenge was calculated based on two parameters.

1. In how many references was the first mile challenge identified?
2. What are the evidence values of references that identified the first mile challenge?

The following formula was used to calculate the evidence score of each challenge. In Equation 1, BEV denotes the base evidence value, representing the value of the most evident reference where a challenge is found.

$$ES = BEV - \left(\sum_{i=2}^{n} \frac{1}{EV_i}\right) \quad (1)$$

where ES is the evidence score, BEV is the base evidence value, and EV is the evidence value of other references that a challenge is identified from (if any).

For example, assuming a challenge appeared in four references with evidence values of 2, 3, 4, and 4, then the BEV would be 2. Meanwhile, EV refers to the evidence values of other references where the challenge was identified, namely 3, 4, and 4. Equation 2 was used to calculate the evidence score of challenge X.

$$\begin{aligned} ES_x &= BEV_x - \left(\sum_{i=2}^{n} \frac{1}{EV_i}\right) \\ ES_x &= BEV_x - \left(\frac{1}{EV_2} + \frac{1}{EV_3} + \frac{1}{EV_4}\right) \\ ES_x &= 2 - \left(\frac{1}{3} + \frac{1}{4} + \frac{1}{4}\right) \\ ES_x &= 2 - 0.83 \\ ES_x &= 1.17 \end{aligned} \quad (2)$$

Subsection 3.2 further describes the analysis of evidence power for first-mile challenges. Subsequently, the ES of the challenges is explored in the QFD framework. The first mile challenges are ranked according to the prioritized importance for the case company.

2.3. Operationalization of challenges (O)

Quality function deployment (QFD) was developed as a practical tool to improve product and service quality by focusing on customer needs and demands (Onar *et al.*, 2016). Even though this method was first introduced conceptually by Akao (1990), it was initially developed and implemented in Japan at the Kobe Shipyards of Mitsubishi Heavy Industries in 1972 (Yazdani, Gonzalez, and Chatterjee, 2019).

QFD is a practical tool that converts consumer demands into quality characteristics, initially focused on the context of product development (Zulkarnain *et al.*, 2023; Yazdani, Gonzalez, and Chatterjee, 2019). As a customer-driven design and manufacturing tool, QFD is prevalent in the field of new product development (Zulkarnain *et al.*, 2023), translating Whats (customer requirements) to Hows (product development engineering characteristics) (Zulkarnain *et al.*, 2023; Zarei, Fakhrzad, and Paghaleh, 2011). Aside from product development, this tool has been widely used in various contexts, including quality improvement, decision support systems, customer satisfaction, and supply chain management. (Yazdani, Gonzalez, and Chatterjee, 2019; Fargnoli *et al.*, 2018). QFD is often portrayed as straightforward, although the application could be more complicated in fields other than product development (Benner *et al.*, 2003). It tends to be helpful when adapted to specific field characteristics.(Benner *et al.*, 2003). Therefore, a modified QFD framework was adopted to operationalize systemic challenges. Methodological information about this framework is provided in *Subsection 3.3*.

3. Results

3.1. Identification and Structuring of First Mile Challenges

Ninety first mile challenges were identified from 66 references with varying levels of evidence. Even though the clusters were naturally interrelated, there was enough data to categorize each challenge distinctly. The identified clusters were *economics, business, finance*, *regulations, natural environment, phenomena*, *supply chain management, logistics*, *skill set, workforce,* and *infrastructure* as shown in Figure 2.

The ever-increasing cost of fuel, often caused by turbulent international politics, negatively affects first mile actors (Raut *et al.*, 2019; Lingjuan, Linhong, and Menghan, 2018). According to Majluf-Manzur *et al.* (2021), developing regions are more vulnerable to these fluctuations. Improving productivity also incurs costs and requires stakeholders to have easy access to credit (Naseer *et al.*, 2019). Additionally, first-mile actors often lacked awareness of downstream SC levels, leading to a mismatch between production and consumption demands, resulting in unproductive processes (Gardas *et al.*, 2019; Naseer *et al.*, 2019). The amount of produce loss is tremendous in the first mile, particularly in developing regions (Patidar and Agrawal, 2020; Gardas *et al.*, 2019; Raut *et al.*, 2019). Farming practices such as irrigation are predominantly executed in an outdated manner (Naseer *et al.*, 2019), which is both unsustainable and economically harmful to producers. Individual perspectives and experiences are more prevalent in guidance rather than scientific management, focusing on improving technical processes and business operations (Parfitt, Brockhaus, and Croker, 2021; Sadati *et al.*, 2021).

The agricultural industry is inherently connected to nature, therefore, it is directly affected by changes in climate, soil, and biodiversity (Isbister, Blackwell, and Riethmuller, 2013). Climate change and extreme weather act as catalysts for other challenges (Despoudi, 2021; Cagliano, Worley, and Caniato, 2016). However, these catalysts were acknowledged as distinct challenges, such as changes in climate and weather alter soil structure, which affected both production and transportation, particularly on unpaved roads due to compaction (Obour *et al.*, 2017; Schjønning *et al.*, 2015).

Regulations are intended to promote the process development of ASC, although it often hinder the use of innovative tools and managerial practices due to bureaucratic barriers in licensing and registration (Gardas *et al.*, 2019; Schjønning *et al.*, 2018; FAO, 2017; DEFRA, 2015). Another challenge is the lack of awareness among first mile ASC actors, particularly farmers, regarding change in regulations (Despoudi, 2021). Facilitated registration processes for new practices, tools, and materials were also identified as a critical need (World Bank, 2019).

The efficiency of SC and the logistics of agricultural produce is highly dependent on the location (Patidar and Agrawal, 2020). As globalization leads to lengthier SC, efficiency becomes increasingly relevant (Gardas *et al.*, 2019; Raut *et al.*, 2019). The cold chain method, which included transportation and storage, required careful planning and investment (Soto-Silva *et al.*, 2017; Tang, Liu, and Chen, 2013). In addition to the lack of cold chain adoption in developing regions, insufficient packaging practices and poor handling persist as ongoing challenges (Asian Development Bank, 2016). Lack of collaboration, coordination, integration, trust, and transparency in ASC processes were the significant challenges identified (Awan *et al.*, 2021; Lingjuan, Linhong, and Menghan, 2018; Patidar *et al.*, 2018).

The Internet of Things and blockchain are two examples of modern technologies that enhance process tracking and support machinery and equipment management at the first-mile stage. However, the adoption of such technologies is limited, particularly in developing regions (Bannor and Kyire, 2021; Yadav, Garg, and Luthra, 2020). The physical accessibility to farmland remained a significant issue, increased by poor and complex road networks that affected all the stakeholders of ASC (Naseer *et al.*, 2019; Raut *et al.*, 2019; European Parliament, 2017).

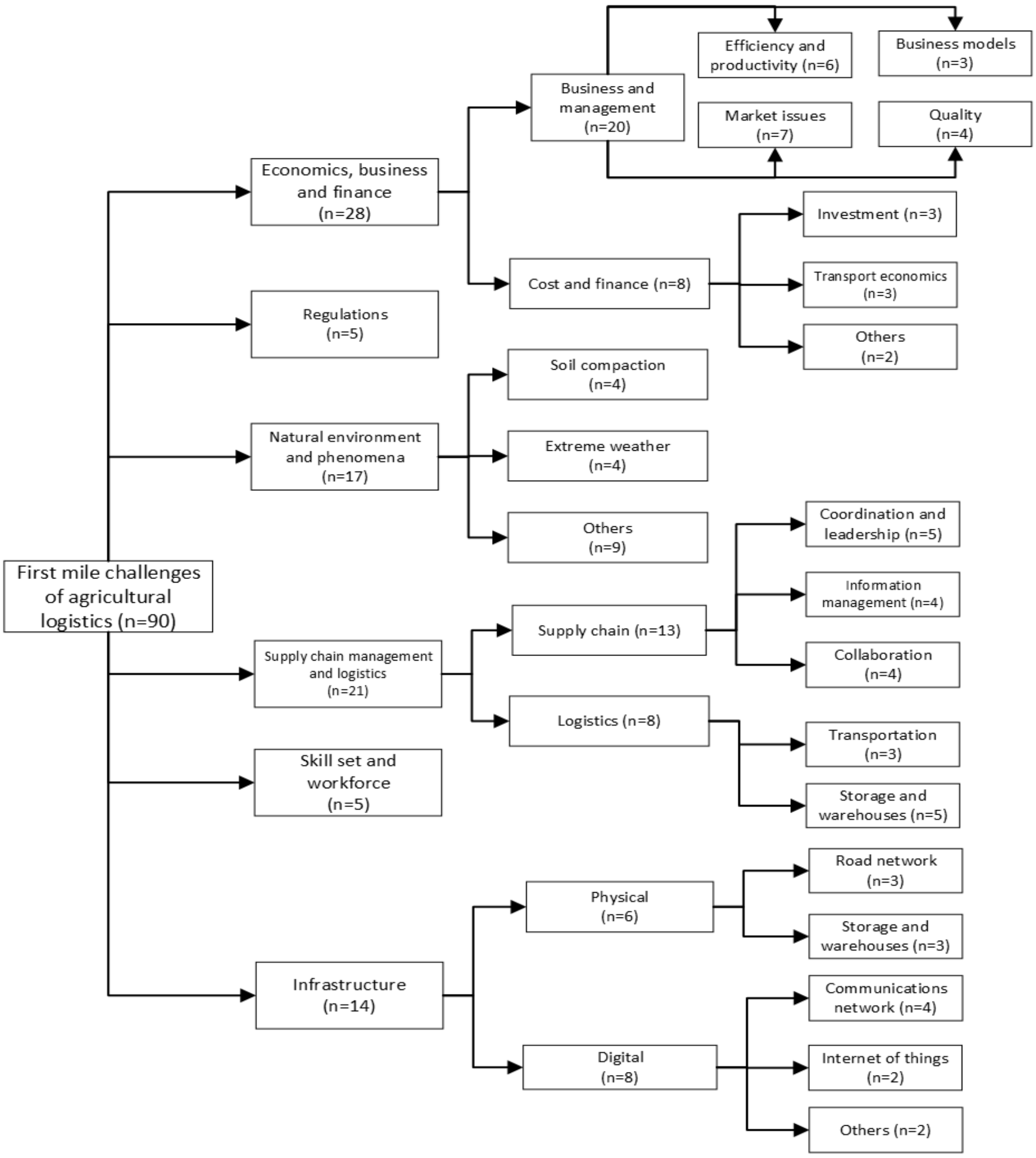


Figure 2 Hierarchical clusters of first mile challenges for agricultural logistics

Despite being a labor-intensive industry, agriculture holds immense potential for technological advancement and automation to reduce repetitive tasks and aid in process monitoring. However, the industry is in high need of skilled and comprehensive professionals (Tang, Liu, and Chen, 2013). The training of stakeholders, particularly at the first mile, is a fundamental need to equip these individuals with the required skills for modern agricultural practices (Despoudi, 2021; OECD-FAO, 2016).

3.2. Evidence Power Analysis

The identified challenges were grouped into three classes based on the evidence power. These categories are as follows

- The evident challenges (n = 21) the evidence scores of first mile challenges in this class were less than the value of 2.72 (M-(s/2)) and identified in at least two references, as shown in Figure 3. M: Median, s: standard deviation

- Median evidence challenges (n = 18) the evidence scores of first mile challenges in this class were higher than the value of 2.72 and lower than the value of 3.88 (M+(s/2)) and were identified at least in two references.
- Recessive challenges (n = 51) This class has two types of challenges. The first group included the first mile challenges with evidence scores higher than 3.88. Meanwhile, the second group comprised challenges identified from only one source, regardless of the evidence score.

The higher the first mile challenges located on the diagram, the more evident the issues. The most prominent challenge identified is *too long SC and excessive circulation links*. *Heavy wastage throughout the SC*, *extreme weather* and *complex and poor road network* were other identified first mile challenges from the literature. The challenges from the regulation cluster were not classified as evident, therefore, it was not shown in Figure 3. The only challenge classified as evident in the *skill set and workforce* was *aging workforce shortage and performance of labor*.

The evident challenges were presented to managers in the case company through semi-structured interviews. For further analysis in the QFD framework, the challenges were ranked with respect to four options, namely *Crucial*, essential, not necessary, and *no information*. However, out of 21 evident first mile challenges, four were identified as crucial from respective perspectives, *too long SC and excessive circulation links*, *high costs in SC*, *fluctuant fuel costs,* and *nontransparent processes*, as shown in Figure 3. Additionally, seven evident first mile challenges were identified as necessary from diverse perspectives, as shown in Figure 3.

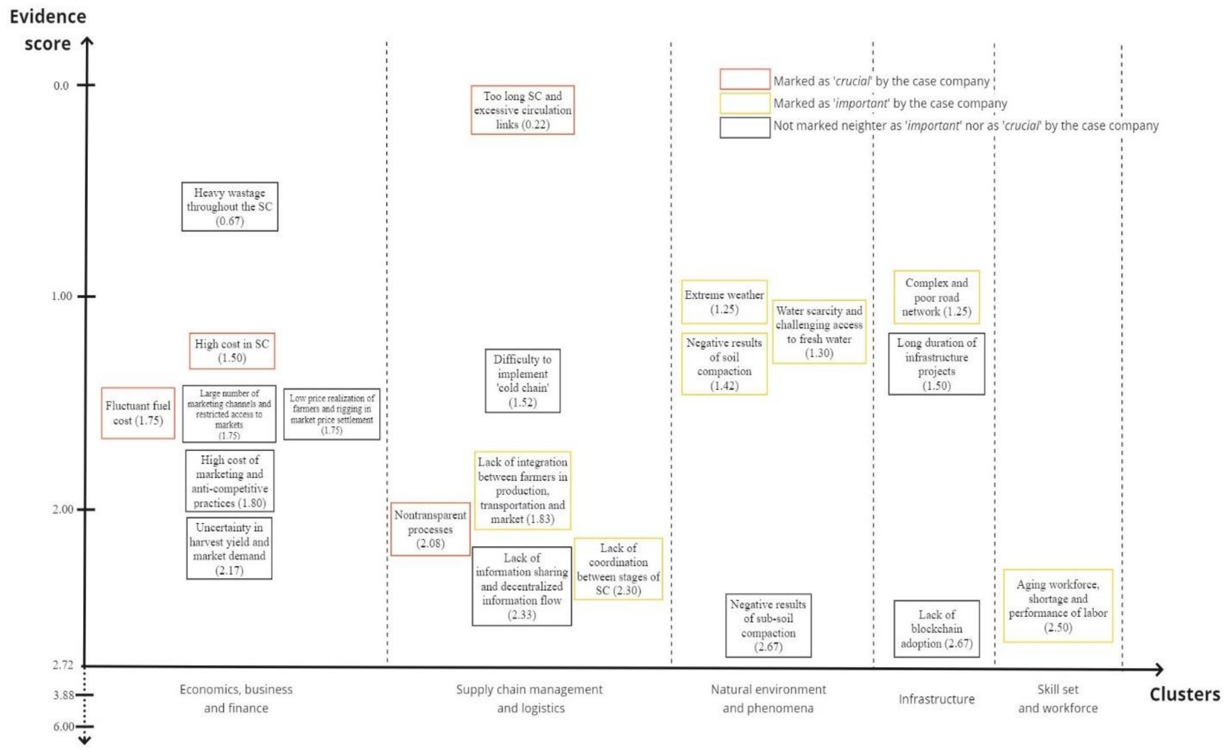


Figure 3 Evident first mile challenges

3.3. Demonstration of QFD

QFD was usually applied through the House of Quality, a matrix-style chart that correlates Whats with Hows, consisting of six submatrices, as shown in Figure 4.

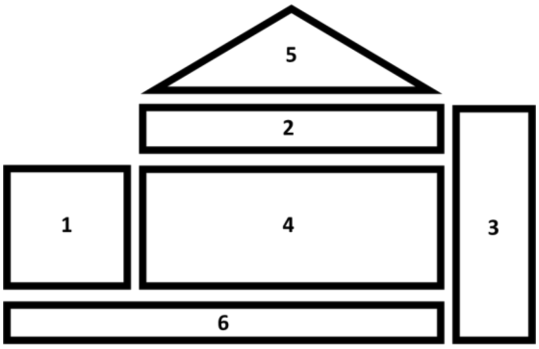


Figure 4 Design of house of quality. Customer requirements (1), technical specifications (2), planning matrix (3), interrelationship matrix (4), technical correlation matrix (5), and technical priorities (6)

In the case of this study, zone 1 represented evident first mile challenges, which are classified based on respective ES, while the ES of each challenge was found in zone 3. Zone 2 consisted of operationalization actions (OAs) aimed at reducing identified challenges. Some identified actions were at a high level, requiring cooperation with regulatory bodies and stakeholders, while others were related to product features. Prospective actions were determined through workshops and meetings with a focus working group.

In zone 3, the planning matrix is comprised of the ES of challenges and value for importance (VFI) specific to the case company. Furthermore, the ES model is described in *Section* 2. VFI were identified through surveys and semi-structured interviews with the case company, using a 4-level likert scale. The evident challenges were ranked as *not significant* (-1), *no information* (0), *important* (3), and *crucial* (5). To accurately reflect the ratings, first mile challenges considered as not important were assigned a value of -1 on the likert scale. Similarly, no information was assigned a neutral value quantified as 0.

The weighted prioritization score (WPS) was located in the far-right column of zone 3 and can be developed in varied ways depending on decision-making needs (Mikhailov, Didehkhani, and Sadi-Nezhad, 2011). Furthermore, the model prioritizes each evident first mile challenge by summing one-third and two-third of the reciprocal of ES and VFI, respectively. The reciprocal of ES was preferred in this model because the smaller the ES, the more evident the first mile challenge.

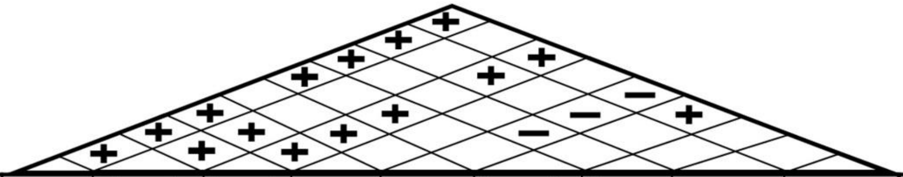
The WPS model was developed for challenge α, using Equation 3.

$$WPS_\alpha = \left(\frac{1}{3} * \frac{1}{ES_\alpha}\right) + \left(\frac{2}{3} * VFI_\alpha\right) \tag{3}$$

For example, the WPS for the challenge of too long SC and excessive circulation links was calculated as follows Equation 4.

$$\begin{aligned} &= \left(\frac{1}{3} * \frac{1}{0.22}\right) + \left(\frac{2}{3} * 5\right) \\ &= 4.85 \end{aligned} \tag{4}$$

Zone 4 served as the core of the house of quality, depicting the quantified relationship level between OAs and evident first mile challenges. The zone connects OAs with the first mile challenges, while the respective quantified relationship levels and symbols are shown in Table 1. The values for relationship levels were used in zone 6 - OAs priority assessment.



Evident First Mile Challenges ↓ / Operationalization Actions →	Cooperate with farmers	Cooperate with other stakeholders of the SC	Cooperate with other vehicle providers	Cooperate with regulators	Decrease the cost of the vehicle	Decrease the pressure of the vehicle to the soil	Improve the safety of the vehicle	Increase the effectiveness of the vehicle	Increase the sustainability of the vehicle	Evidence score (ES)	Value for importance for the company (VFI)	Weighted prioritization score (WPS)	Normalized values of WPS
Heavy wastage throughout the SC	○	○	○	○						0.67	-1	-0.17	0.07
High cost in SC	○	○	○	○	○					1.50	5	3.56	0.76
Fluctuant fuel cost				●	△					1.75	5	3.52	0.75
Large number of marketing channels and restricted access to markets		○		○						1.75	0	0.19	0.14
Low price realization of farmers and rigging in market price settlement	○			○						1.75	0	0.19	0.14
High cost of marketing and anti-competitive practices	○			○						1.80	0	0.19	0.13
Uncertainty in harvest yield and market demand		○								2.17	0	0.15	0.13
Too long SC and excessive circulation links	○	●	○	○	○					0.22	5	4.85	1.00
Difficulty to implement 'cold chain'	○	○								1.52	0	0.22	0.14
Lack of integration between farmers in production, transportation and market	●			○						1.83	3	2.18	0.51
Nontransparent processes	○	●	○	○						2.08	5	3.49	0.75
Lack of coordination between stages of SC	○	●	○	○						2.30	3	2.14	0.50
Lack of information sharing and decentralized information flow	○	○	○	○						2.33	-1	-0.52	0.00
Extreme weather	○							●	○	1.25	3	2.27	0.52
Water scarcity and challenging access to fresh water				●				●		1.30	3	2.26	0.52
Negative results of soil compaction			○	○		●		○		1.42	3	2.23	0.52
Negative results of sub-soil compaction			○	○		●		○		2.67	-1	-0.54	0.00
Complex and poor road network	○	○	○	●						1.25	3	2.27	0.52
Long duration of infrastructure projects				●						1.50	0	0.22	0.14
Lack of blockchain adoption	○	○								2.67	-1	-0.54	0.00
Aging workforce, shortage and performance of labor							●			2.50	3	2.13	0.50
Priority Score of Operationalization Actions (PSOA)	73.45	109.84	51.93	127.79	28.74	15.24	19.20	45.79	6.80				
Normalized values of PSOA	0.55	0.85	0.37	1.00	0.18	0.07	0.10	0.32	0.00				

Figure 5 Demonstration of House of Quality

Table 1 Relationship levels and symbols

Symbols	Relationship Level	Value
●	Strong	9
○	Moderate	3
△	Weak	1

Zone 5 showed the mutual and reverse relationships between prospective OAs, which were depicted by (+) and (-), respectively. This zone enabled decision makers to understand how the implementation of an action affected others. In particular, it allows decision makers to discern how closely ranked actions relate to each other. Assuming an action facilitates the implementation of others (more +), then the decision maker can prioritize it over the other.

In zone 6, the priority of OAs was assessed by determining the relationship matrix values and the WPS. This included summing the products of WPS for each first mile challenge and the corresponding value in the relationship matrix for each OAs connected in the same pathway (Wicaksono and Illés, 2022). The model for prioritizing the score of OAs is stated as follows in Equation 5.

$$\sum_{i=1}^{n} RL_i \; x \; WPS_i \tag{5}$$

Where RL is the relationship level between a particular challenge and operationalization action. For example, to calculate the priority score for Decrease the cost of the vehicle:

$$\begin{aligned} &= (3*4.85) + (3*3.56) + (1*3.52) \\ &= 28.45 \end{aligned} \tag{6}$$

4. Discussion

This study sheds light on first mile challenges of ASC and their transformation into actionable operations through an agri-machinery case. The transformation of these overarching challenges into operationalization actions that guide further innovative solutions were illustrated through exploration. Furthermore, a practical application with prospective tools was demonstrated, with the introduction of a comprehensive four-step process known as ISPO (identification, structuring, prioritization, and operationalization). Initially, 90 first mile ASC challenges, clustered around six themes as shown in Figure 2, were identified, but after evidence power analysis, the number reduced to 21. Figure 3 showed that the case company identified 11 of these as important or crucial. Using QFD, nine challenges were prioritized with normalized WPS exceeding 0.5. Finally, cooperating with other stakeholders of the SC, including regulators and farmers, was considered critical in effectively addressing prioritized first mile challenges, as shown in Figures 5 and 6.

Technological advancement and sustainability are prominent themes in research on the agricultural supply chain (ASC). However, significant attention has been paid to the overall supply chain or downstream aspects rather than the upstream segment (Abdullahi *et al.*, 2024; Heryani *et al.*, 2022; Jianying *et al.*, 2021). Few research has focused on the specific challenges of the upstream segment (Dasgupta, Kanchan, and Kundu, 2019; Lingjuan, Linhong, and Menghan, 2018), with Naseer *et al.* (2019) significantly reporting critical issues. Despite this, the operationalization of systemic challenges at the company level remained unexplored. The present study sought to bridge this gap by developing conceptual framework endeavors to exemplify the transformation of systemic challenges into enhanced technological solutions and operationalization actions (OA) demonstrated as a case study on agricultural machinery. Due to scarce resources, the process of prioritization becomes important to guide actions, concentrating on the significance of discerning the relative importance of various contextual actions.

Thicker arrows in the figure reflect a strong relationship, while thinner arrows reflect a moderate relationship. With the help of the QFD framework, organizations can strategically divert efforts to more effective areas in line with prioritized solution demands (Zulkarnain *et al.*, 2023). Figure 6 shows evident first mile challenges and OA with normalized WPS values and priority scores greater than 0.50. These OA were the most critical plan for reducing challenges at the ASC first mile stage. Majority of the OAs operate at a strategic level, complementing each other, while actions related to product development, such as *improving the safety of the vehicle*, have a more complicated relationship. For example, improving the safety of the vehicle may lead to increased costs. However, the illustrated critical OAs operate at a strategic level and show positive or mutually beneficial relationships, indicating that implementing one action facilitates the others listed.

The operationalization action plan included *cooperating with regulators*, *other stakeholders of the SC*, and *farmers* as a result of the proposed framework for the agri-machinery case company. The action of *cooperating with regulators* was reported to be the most critical. The first mile challenges with higher WPS were strategically positioned, requiring cooperation with and support from regulatory bodies. For example, addressing challenges related to *complex and poor road network*, *fluctuating fuel costs* and *water scarcity, as well as challenging access to fresh water* strongly depended on cooperation with these regulatory bodies (Gardas *et al.*, 2019; Naseer *et al.*, 2019; Tang, Liu, and Chen, 2013). To address the challenge of *a complex and poor road network*, additional cooperation efforts with farmers and other stakeholders of the SC are essential. Similarly, *high costs in SC, nontransparent processes, extremely lengthy SC, and excessive circulation links* are other first mile challenges that require a cooperation network (Awan *et al.*, 2021; Raut *et al.*, 2019; Lingjuan, Linhong, and Menghan, 2018).

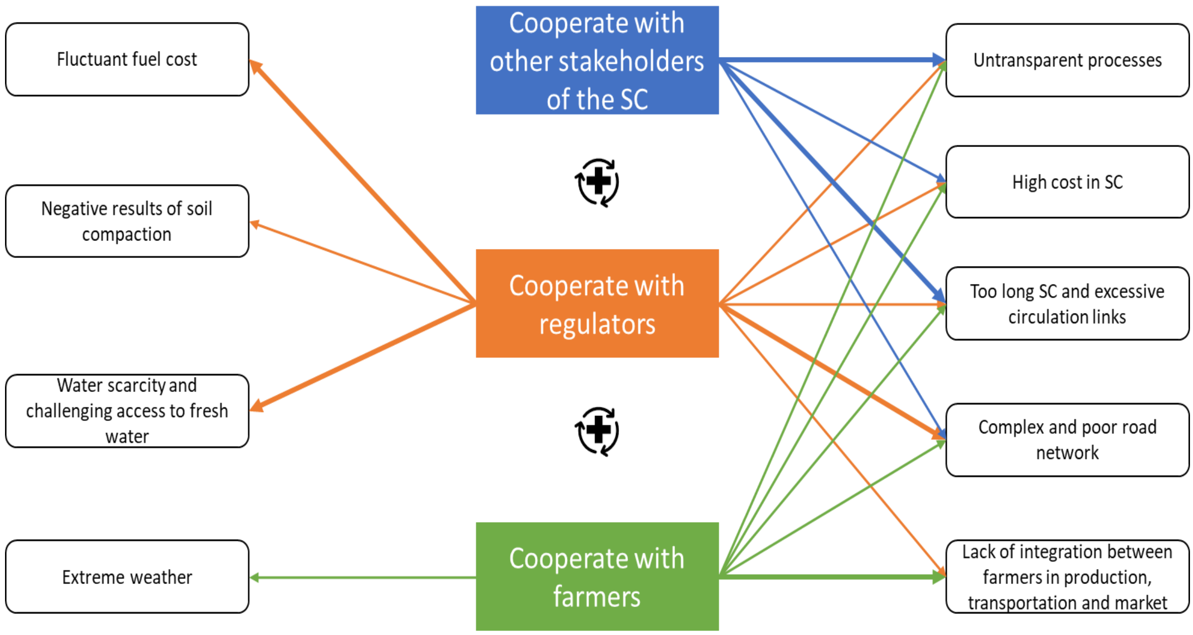


Figure 6 Critical operationalization actions and first mile challenges

The *negative impacts of soil compaction* are unique to the first mile stage of SC, as opposed to several other challenges that tend to affect other stages. Meanwhile, since the soil can easily be compacted by agriculture machinery and equipment during logistics operations around the field (Schjønning *et al*., 2016; DEFRA, 2015), stricter regulations and monitoring by regulatory bodies need to be implemented. Farmers, typically operating on a small scale, often lack integration in production, transportation, and marketing (Majluf-Manzur *et al.*, 2021; Gardas *et al.*, 2019; Tang, Liu, and Chen, 2013). This challenge can be addressed through cooperation among farmers and regulatory support. Finally, extreme weather conditions influenced by other factors require collective solutions. While farmers can be well trained in handling such conditions, cooperation and support are essential for effective mitigation.

5. Conclusions

This study investigates the primary challenges faced by ASC and their translation into actionable operations using a case study involving agricultural machinery. It illustrates the transformation of these challenges into practical steps through the ISPO framework: Identification, Structuring, Prioritization, and Operationalization. In this context, the study significance focused on the instrumental value, drawing from constructive methodologies. The present investigation inevitably had a number of limitations. Firstly, the Scopus search was limited to titles, potentially excluding relevant references discussing first mile challenges solely within the text. Secondly, grey literature searches were limited to available online reports, possibly overlooking significant offline resources. Additionally, some references were excluded due to limited discussion of target concepts. Exclusion decisions included multiple research projects to ensure objectivity. Finally, the developed method required testing across diverse ASC stakeholders, as it was only applied in one agri-machinery use case. The proposed process represented a construct awaiting validation through subsequent research and practical implementation. Further research needs to be conducted, concentrating on applying the same method to different ASC stakeholders.

Acknowledgments

The authors are grateful to Docent Professor David Edwards for his significant support and insights in this research. The authors are also grateful to the LEVITOI partners for funding this research through the Business Finland (Grant ID 3509/31/2021).

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