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Prioritising Visibility Influencing Factors in Supply Chains for Resilience

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Abstract

Supply chain resilience is essential, especially in helping supply chains prepare, react, and grow from supply chain disruptions. Competencies required to generate supply chain performance through resilience include, amongst others, visibility, digital technologies, and supply chain relationships. Supply chain visibility is the ability of the supply chain to see clearly from one end to another whilst sharing information that is key or useful to the stakeholders in the chain. Effective management of supply chain visibility can result in a competitive advantage. This requires knowledge and understanding of the factors influencing visibility and appropriate prioritisation of the factors. This paper presents a method of prioritising visibility influence factors (VIFs) in supply chains and resilience. It adopts a fuzzy logic approach and explores prioritisation from two main perspectives: a) supply chain managers included more towards digital technologies perspectives (DTP), and b) supply chain managers included more towards supply chain relationship perspectives (SCRP). Remarkably, notable differences were found between the VIF priorities of the DTP vs the SCRP supply chain managers. Automation, context awareness, dynamic capability, absorptive capacity, and information management were top VIF priorities for the DTP managers. Supply chain relationships, nature of management, Resources, Linkages, and Laws, policies and standards came tops as VIFs to prioritise for the SCRP manager. Interestingly, both the DTP and SCRP participants in the study attach somewhat similar views on priorities regarding motives, information sharing, interoperability, integration and connectivity of information technologies. There are reasonable arguments in support of the viewpoints. Appropriate good balance may need to be sought between the DTP and the SCRP perspectives when prioritising the VIFs for resilience.

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1. Introduction

Resilience arises from the Latin word 'resilire' which means to rebound, and it describes a system's ability to overcome shock by 'rebounding' to the original state [1]. It relates to the capacity for quick recovery from difficulties. In recent years, supply chain resilience has increasingly taken a prominent role in protecting the chain and combating vulnerabilities to disruptions such as those arising from the COVID-19 pandemic. Supply chain resilience is essential, especially in helping supply chains prepare, react, and grow from supply chain disruptions [1]. Disruption can impact supply, logistics, and in-house activities and can result from natural hazards/disaster-related disruptions [1, 2]. Supply chain resilience is the "adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function" [3]. Competencies required to generate supply chain performance through resilience include resourcefulness, flexibility, adaptability, efficiency, anticipation, dispersion, financial strength, and end-to-end visibility throughout the supply chain [4]. To support performance, control (e.g. logistics, costs), coherence (e.g. contingency planning), and connectedness (e.g. information technology) is also essential [3].

Several strategies are available to supply chains to enhance their resilience. The strategies can be categorised into three: preparedness, response, and recovery [5]. [6] described three phases of supply chain resilience, namely, pre-disruption, recovery, and supply chain redesign, where supply chain redesign provides an opportunity to support readiness for future disruptions. In these categorisations and phases, flexibility, collaboration, and visibility have been found to be frequently occurring terms across the supply chain [7].

Supply chain visibility has been defined as how actors within the chain have access to or share mutually beneficial information that is key or useful to their operations and supports decision-making [8]. It is the ability of the supply chain stakeholders to see clearly from one end to another whilst sharing information that is key or useful [8]. The goals of supply chain visibility include the reduction of business and supply chain risk, enhancing resilience, improving lead times, and enhancing performance and competitive advantage [8]. Several techniques are available for assessing supply chain visibility as a prerequisite for supply chain visibility management and improvement programmes (e.g. [9–11]). Underlying the assessment methods are the influencing factors of supply chain visibility [12–14] Knowledge and understanding of the supply visibility influencing factors and their prioritisation are essential as part of the considerations for supply chain resilience.

Alongside supply chain visibility, the importance of relational strategies, supply chain relationships, collaboration, and digital technologies have been acknowledged in the supply chain resilience literature. Digital technologies are essential for supply chain resilience by supporting preparedness, response, and recovery [15]. For example, Artificial intelligence (A.I.) analyses, activates a response for resilience and supports supply chain reconfiguration, visibility, sourcing and distribution [16]. Blockchain technology supports connectivity between supply chain partners, improving visibility and transparency [17] and the internet of things (IoT) through the linking of digital and physical entities [18].

The literature on supply chain visibility and supply chain resilience is evolving. However, a research gap lies in how to prioritise supply chain visibility influencing factors to, for example, support supply chain resilience. This paper addresses this research gap. It presents an approach to prioritising the factors influencing supply chain visibility and explores the prioritisation from two viewpoints, supply chain managers whose inclination is toward digital technologies and supply chain managers included more towards supply chain relationships. The remainder of the report begins with highlighting supply chain visibility influencing factors in Section 2, and Section 3 contains the research methodology adopted in the paper. This is followed by a case study, its results and a discussion in Section 4. The final section of the paper i.e. Section 5, contains the conclusion and suggested areas for future work.

2. Related work on Supply Chain Influencing Factors

Research is starting to identify the key factors and enablers for visibility in supply chains. [13] conducted a systematic literature review highlighting the key drivers, effects, barriers and challenges, and antecedents of supply chain visibility. Responsible sourcing, supply base management, price advantage, purchasing power, compliance, customer service, market intelligence, and modular design were vital drivers. Antecedents were noted to include culture, collaboration, trust, business alignment, information sharing, information quality, integration, blockchain, collaborative planning system, and RFID. Barriers and challenges are budgets, limited by first-tier suppliers, risk of business loss, budget constraints, poor data quality, and reluctance to provide data. Capabilities included agility, analytics, decision-making support, planning, risk management, profitability, quality and safety, and sustainability.

Information sharing is an important antecedent of supply chain visibility [8], and knowledge of the information sharing influencing factors can shed some light on the factors influencing supply chain visibility. In understanding the factors influencing information sharing in supply chains, [14] identified six main categories: technology, information, power structure, business process, legal, and culture.

[12] conducted a study to identify the factors influencing visibility in sustainable supply chains. Fourteen main factors listed in Table 1 were identified. The factors in Table 1 indicate that desirable visibility levels can be achieved through adopting digital technologies and automation, improved integration of quality information, supply chain relationships, enhancement of management capabilities, and sustainability awareness.

Table 1. Factors Influencing sustainable supply chain visibility (Adapted from [12]).

Factors	Description
Automation	This is the creation and application of technologies to produce and deliver goods and services with minimal human intervention.
Context Awareness	This is awareness of the circumstances that form the setting for visibility and in terms of which it can be fully understood.
Dynamic Capability	This is the ability of supply chains to reconfigure their competencies, both internal and external competencies to deal with changes in the supply chain.
Absorptive Capacity	This is a supply chain's ability to recognise the value of new information, assimilate it, and apply it to commercial ends. The associated concept of green absorptive capacity captures environmental aspects.
Information management	This concerns the acquisition of information from one or more sources, the custodianship, the distribution of the information to those who need it, and its ultimate disposition through archiving or deletion.
Information quality	This is the quality of the content of information. It is often described as the fitness to use the information provided.
Information Sharing	This describes the exchange of information between various organisations, people, and other entities. It is the act of making information possessed by one entity available to another entity's technologies.
Motives	This is described as the drive to make SSC (Sustainable Supply Chain) visible.
Integration and Connectivity	This refers to the connections of applications so that data from one system can be accessed by the other in a supply chain.
Interoperability and Integrating	This is described as the capacity for two systems to work together without having to be altered to do so. This has also been recognised for its ability to create and develop synergies between partnering organisations.
Laws, Policies and Standards	This is a standard compliance clause used in agreements that aims to ensure a party's compliance with applicable laws, policies, and standards.
Linkages	This is the interactions between tasks, functions, departments, and organisations, that promote the flow of information, ideas, and achievement of shared objectives in a supply chain.
Resources	This is an economic or productive factor required to accomplish an activity, or as means to undertake an enterprise and achieve desired outcome.
Nature of Management.	The nature of management involves organising personnel and associated resources, managing them with a level of commitment and involvement. Management should adopt an appropriate approach, be purposeful, dynamic, creative, and incorporate continuous improvement.
Supply chain relationship	This is an agreement formed between two or more independent stakeholders within a supply chain to ensure that a specific goal or interest is achieved.

Amongst the factors listed in Table 1 are digital technologies, automation, and supply chain relationships, which are essential for supply chain resilience and are studied further in this paper. This paper uses Table 1 as an illustration of a method of prioritising visibility influencing factors for resilience [11].

3. Methodology

This study adopts a case study approach. Case study has been applied in previous studies of supply chain resilience, e.g. [19]. The approach is recognised as a method of understanding a phenomenon within a specific context over a specified period [20]. Case study protocol entails developing research questions, methods, interpretation process, and criteria for assessment. A five-step model for case study research design is discussed by [20,21] as shown in Fig. 1, and the model is adopted in this paper.

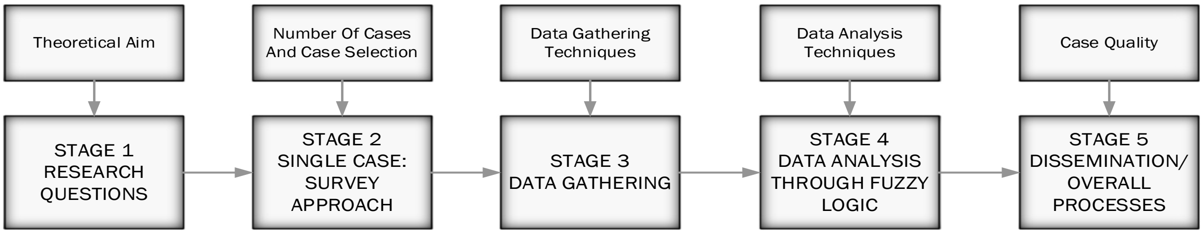

Fig. 1 Overall Research Adapted from [20,21]

Fuzzy logic is central to the prioritisation method presented in this paper and used in Stage 4 in Figure 1. Fuzzy logic is an increasingly popular approach for solving supply chain and operations-related problems. For example, to prioritise features of a supply chain digital platform [22], sustainable supplier selection [23], and in the assessment of visibility levels in sustainable supply chains [11]. In using fuzzy logic, a fuzzy number is used to establish a position of truth in an uncertain situation and engage in exhortative research designs, such as this paper. A fuzzy number represents a range of values for a specific variable, often translated into a linguistic variable.

The steps in the fuzzy approach to prioritising the visibility influencing factors are as follows.

Step 1: Consider there are visibility influencing factors $VIF_i,\ i\ \in \{1,2 \ldots I\}$. Establish the set of VIFs.

Step 2: Obtain data expert opinions on pairwise comparison of the VIFs to obtain a pairwise comparison matrix. The pairwise comparison in this paper is based on linguistic variables shown in Table 2 below.

Table 2.Linguistic Variables and Associated Triangular Fuzzy Numbers (Adapted from [24]).

Linguistic Variable	Triangular Fuzzy Numbers (TFN)	Reciprocal TFNs
Equally Important (E)	(1, 1, 1)	(1, 1, 1)
Weakly Important (W)	(1, 3, 5)	(1/5, 1/3, 1)
Fairly Important (F)	(3, 5, 7)	(1/7, 1/5, 1/3)
Strongly Important (S)	(5, 7. 9)	(1/9, 1/7, 1/5)
Absolutely Important (A)	(7, 9, 11)	(1/11, 1/9, 1/7)

For example, an expert could see VIF_1 as weakly important when compared with VIF_2 in which case the corresponding entry on the pairwise comparison matrix will be W, i.e. weakly important.

Step 3: Translate the linguistic variables in the pairwise comparison matrix to triangular fuzzy numbers (TFNs) to obtain a TFN Pairwise Comparison Matrix. Triangular fuzzy numbers are widely adopted because they represent data in a fuzzy environment. TFNs are composed of a lower (l), middle (m), and upper number (u), representing the values of a fuzzy event. Equation 1 shows the mathematical representation of the fuzzy event [24,25], while Fig. 2 illustrates the TFN in graphical form.

$$\mu_A(x) = \begin{Bmatrix} 0 & x < l; \\ \frac{x-l}{m-l} & l \le x \le m; \\ \frac{m-x}{u-m} & m \le x \le u; \\ 0 & x > u. \end{Bmatrix} \quad (1)$$

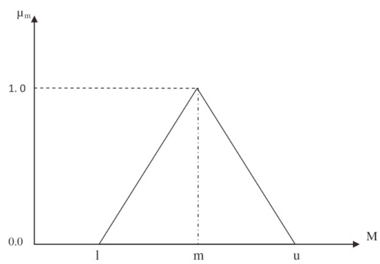

Fig. 2: A Triangular Fuzzy Number Adopted from [25,26]

The triangular fuzzy numbers and reciprocal fuzzy numbers shown in Table 2 are used in this paper. For example, following on from the illustration in Step 2 above, the VIF_1 pairwise comparision with VIF_2 will be translated to triangular fuzzy number (1,3,5) in the TFN Pairwise Comparison Matrix.

Step 4: Calculate the importance weights of the visibility influencing factors based on the TFN Pairwise Comparison Matrix entries. This is done in the following three sub-steps.

Step 4.1: If there are more than one expert involved in the prioritisation, calculate the fuzzy geometric mean of the expert opinion, using the method introduced in [27]. This will result in a Fuzzy Geometric Mean Pairwise Comparison Table.

Step 4.2: Determine the fuzzy relative importance weight or the fuzzy synthetic extent of each of the VIF_i visibility influencing factors, using the extent analysis method [28]. The calculation follows the approach in [28]. To calculate the fuzzy relative weight (Si) a goal is set for each round of assessment and is represented as G={g1, g,2, g,3, g,4, gn}. The m extent value is obtained as $M_{gi}^{1}, M_{gi}^{2}, M_{gi}^{3}, M_{gi}^{4}, M_{gi}^{m}$, where gi (i=1,2,3,…n) is the goal set and M_{gi}^{j}, (j=1,2,3,….m) represent all TFNs. The fuzzy synthetic extent is shown in Equation (2) below.

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \tag{2}$$

The calculation of $\sum_{j=1}^{m} M_{gi}^{j}$ is done by using a fuzzy addition extent of m for a specific matrix, as shown in Equation (3). The variables l, m, and u, represent the lower, middle, and upper possible values, respectively.

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} lj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} uj\right) \tag{3}$$

Next is to calculate $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]$ by performing additional fuzzy addition operation of M_{gi}^{j}, (j=1,2,3,….m) as shown in Equation (4).

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} lj, \sum_{i=1}^{n} mj, \sum_{i=1}^{n} uj\right) \tag{4}$$

The last step is to calculate the vector inverse value $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$, as shown in Equation 5.

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \frac{1}{\sum_{i=1}^{n} ui}, \frac{1}{\sum_{i=1}^{n} mi}, \frac{1}{\sum_{i=1}^{n} li} \tag{5}$$

Step 4.3: Defuzzify the fuzzy criteria weights. This is done by using the best non-fuzzy priority (BNP) method from [29, 30] to calculate crisp weights for each of the $VIF_i,\ i \in \{1,2 \ldots I\}$.

4. Case Study

The case study was identified through purposive sampling. The selected firm has been active before and throughout the COVID-19 pandemic and has remained in business. In addition, the selected firms' supply chain is internationally based. The case study is conducted on a European-based food manufacturing and distribution company active throughout western Europe. The company, referred to in this paper as Company X, has locations in the United Kingdom, the Netherlands, Ireland, and Italy and operates in an expanding list of European countries. Company X's main product is traditional pizza ingredients, and the company also provides professional cooking equipment and advice to its customers. Company X is BRC food certified and is an award-winning business.

Three supply chain managers in Company X participated in this case study. The summary of participants is shown in Table 3. The three participants represented various locations where supply chain and operational activity were managed, namely the U.K., Italy, and Ireland. The locations fall under the same ownership. The experience and challenges at each location provide a rich and diverse response for the case study.

Table 3: Overview of Participants

Participant	Role in Organisation	Position/Level	Experience in Current Organisation	Total Years' Experience	Employees on location	Firm Type
1	Operations/Supply Chain Manager (Technology Driven)	Senior	10	10	10+	Private
2	Operations/Supply Chain Manager (Technology Driven)	Top Management	8	15	60-70	Private
3	Operations/Supply Chain Manager (People Driven)	Senior M	7	7	15	Private

In the case study, two of the participants were included more towards the use of digital technologies for advancing supply chain visibility, whilst the third participant is inclined towards supply chain relationships. These perspectives are captured in this case study as the digital technology perspective (DTP) and Supply chain relationship perspective (SCRP). Each of the three participants individually provided their perspectives through a questionnaire. Two participants held the DTP, while one held an SCRP. Based on participant responses and the analysis, the results of DTP and SCRP provide an understanding of the practices and the importance of differing perspectives in an organisation.

4.1. Results

The data collected from the DTP participants and the SCRP participant were analysed separately. The details of the analysis for the DTP participants are presented first, as follows. The pairwise comparison matrix obtained from the DTP participants is shown in Table 4, with the participant's responses shown as experts 1 and 2, respectively.

The results from Table 4 are translated into TFNs for Experts 1 and 2. Table 5 presents an example of the translation for F1 (Automation).

Table 4: Pairwise Comparison Matrix Respondents 1 and 2

Factor	Expert	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
F1	1	**E**	F	S	F	S	F	W	W	W	W	E	E	W	W	F
	2	**E**	A	A	A	E	E	E	A	E	A	E	A	A	A	A
F2	1	F-1	**E**	W	W	F	F	W	W	W	W	W	E	W	W	F
	2	A-1	**E**	W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1
F3	1	S-1	W-1	**E**	W	F	F	W	W	W	F	W	W	W	W	F
	2	A-1	W	**E**	E	A	E	E	A	E	E	E	E	A	A	E
F4	1	F-1	W-1	W-1	**E**	F	F	W	W	F	F	W	W	F	W	S
	2	A-1	W	E	**E**	W	W	W	W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1
F5	1	S-1	F-1	F-1	F-1	**E**	F	F	W	W	F	W	W	W	F	F
	2	E	W	A-1	W-1	**E**	A	A	A	E	E	E	E	A	A	E
F6	1	F-1	F-1	F-1	F-1	F-1	**E**	F	W	F	F	W	W	F	F	F
	2	E	W	E	W-1	A-1	**E**	E	A	E	E	E	E	A	A	E
F7	1	W-1	W-1	W-1	W-1	F-1	F-1	**E**	W	F	F	W	W	F	F	F
	2	E	W	E	W-1	A-1	E	**E**	A	E	E	E	E	A	A	E
F8	1	W-1	W-1	W-1	W-1	W-1	W-1	W-1	**E**	F	W	F	W	F	F	F
	2	A-1	W	A-1	W	A-1	A-1	A-1	**E**	F-1	F-1	F-1	F-1	F-1	F-1	F-1
F9	1	W-1	W-1	W-1	F-1	W-1	F-1	F-1	F-1	**E**	F	W	W	F	F	S
	2	E	W	E	W	E	E	E	F	**E**	E	E	E	A	A	E
F10	1	W-1	W-1	F-1	F-1	F-1	F-1	F-1	W-1	F-1	**E**	W	W	W	F	F
	2	A-1	W	E	W	E	E	E	F	E	**E**	E	E	A	A	E
F11	1	E	W-1	W-1	W-1	W-1	W-1	W-1	F-1	W-1	W-1	**E**	W	W	W	F
	2	E	W	E	W	E	E	E	F	E	E	**E**	E	F	F	E
F12	1	E	E	W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1	W-1	**E**	F	F	F
	2	A-1	W	E	W	E	E	E	F	E	E	E	**E**	A	A	E
F13	1	W-1	W-1	W-1	F-1	W-1	F-1	F-1	F-1	F-1	W-1	W-1	F-1	**E**	F	F
	2	A-1	W	A-1	W	A-1	A-1	A-1	F	A-1	A-1	F-1	A-1	**E**	W-1	W-1
F14	1	W-1	W-1	W-1	W-1	F-1	F-1	F-1	F-1	F-1	F-1	W-1	F-1	F-1	**E**	F
	2	A-1	W	A-1	W	A-1	A-1	A-1	F	A-1	A-1	F-1	A-1	W	**E**	W-1
F15	1	F-1	F-1	F-1	S-1	F-1	F-1	F-1	F-1	S-1	F-1	F-1	F-1	F-1	F-1	**E**
	2	A-1	W	E	W	E	E	E	F	E	E	E	E	W	W	**E**

Table 5: Pairwise Comparison Matrix Respondents 1 and 2 in TFN (F1 Automation)

Ranking	Expert	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
	1	**(1, 1, 1)**	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(1, 1, 1)	(1, 1, 1)	(1, 3, 5)	(1, 3, 5)	(3, 5, 7)
F1	2	**(1, 1, 1)**	(7, 9, 11)	(7, 9, 11)	(7, 9, 11)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(7, 9, 11)	(1, 1, 1)	(7, 9, 11)	(1, 1, 1)	(7, 9, 11)	(7, 9, 11)	(7, 9, 11)	(7, 9, 11)

Next, Step 4 of the fuzzy approach described in Section 3 above is carried out for Tables 4 and the associated TFN Pairwise Comparison Table (Extract in Table 5). The calculates crisp weights for each of the $VIF_i,\ i\ \in \{1,2 \ldots 15\}$ is shown in Table 6 below.

Table 6: Ranking of Factors (DTP).

Rank	LV	Consolidated	Value
1	F1	Automation	0.1891
2	F5	Information Management	0.1306
3	F3	Dynamic Capability	0.1218
4	F6	Information Quality	0.1037
5	F7	Information Sharing	0.1018
6	F9	Integration and Connectivity	0.0875
7	F4	Absorptive Capacity	0.0826
8	F12	Linkages	0.0793
9	F10	Interoperability and Integrating	0.0758
10	F11	Laws, Policies and Standards	0.0659
11	F2	Context Awareness	0.0585
12	F8	Motives	0.0367
13	F13	Resources	0.0335
14	F14	Nature of Management.	0.0304
15	F15	Supply Chain Relationship	0.0249

The SCRP participant's results are shown in Tables 7 (the pairwise comparison) and 8 (resulting weights and prioritisation).

Table 7 Pairwise Comparison Matrix LV (SCRP)

Respondent 3	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
F1	E	S-1	S-1	F-1	A-1	S-1	A-1	F-1	S-1	A-1	S-1	S-1	S-1	S-1	A-1
F2	S	E	S-1	F-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1
F3	S	S	E	S-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1	S-1
F4	F	F	S	E	A-1	A-1	A-1	S-1	S-1	S-1	A-1	S-1	S-1	S-1	S-1
F5	A	S	S	A	E	S-1	S-1	S-1	S-1	S-1	F-1	F-1	F-1	F-1	F-1
F6	S	S	S	A	S	E	A-1	A-1	A-1	A-1	S-1	S-1	S-1	S-1	A-1
F7	A	S	S	A	S	A	E	A-1	A-1	A-1	F-1	S-1	S-1	S-1	A-1
F8	F	S	S	S	S	A	A	E	S-1	S-1	S-1	S-1	S-1	S-1	S-1
F9	S	S	S	S	S	A	A	S	E	A-1	S-1	S-1	S-1	S-1	A-1
F10	A	S	S	S	S	A	A	S	A	E	F-1	S-1	S-1	S-1	S-1
F11	S	S	S	A	F	S	F	S	S	F	E	F-1	F-1	F-1	F-1
F12	S	S	S	S	F	S	S	S	S	S	F	E	F-1	F-1	S-1
F13	S	S	S	S	F	S	S	S	S	S	F	F	E	S-1	S-1
F14	S	S	S	S	F	S	S	S	S	S	F	F	S	E	S-1
F15	A	S	S	S	F	A	A	S	A	S	F	S	S	S	E

Table 8 Ranking of Factors (SCRP)

Rank	LV	Expert 3	Value
1	F15	Supply chain relationship	0.1482
2	F14	Nature of Management.	0.1246
3	F13	Resources	0.1147
4	F12	Linkages	0.1078
5	F10	Interoperability and Integrating	0.1042
6	F11	Laws, Policies and Standards	0.0982
7	F9	Integration and Connectivity	0.0886
8	F8	Motives	0.0760
9	F7	Information Sharing	0.0717
10	F6	Information quality	0.0563
11	F5	Information Management	0.0500
12	F4	Absorptive Capacity	0.0284
13	F3	Dynamic Capability	0.0242
14	F2	Context Awareness	0.0144
15	F1	Automation	0.0044

4.2. Discussion

There are some remarkable differences in the results of the DTP (in Table 6) and the SCRP (in Table 8) participants. Both similarities and differences are found in the responses of the participants. Notable similarities were found between the participants making up the DTP group that highlights their inclination toward digital technology for visibility enhanced supply chain resilience in their pairwise comparisons of the VIFs.

The response from the SCRP participant was remarkably different from those of the DTP group, with the SCRP participant highlighting its supply chain relationship perspectives to visibility enhanced supply chain resilience. Fig. 3 shows an overview of the prioritisations of the supply chain VIFs obtained from the case study.

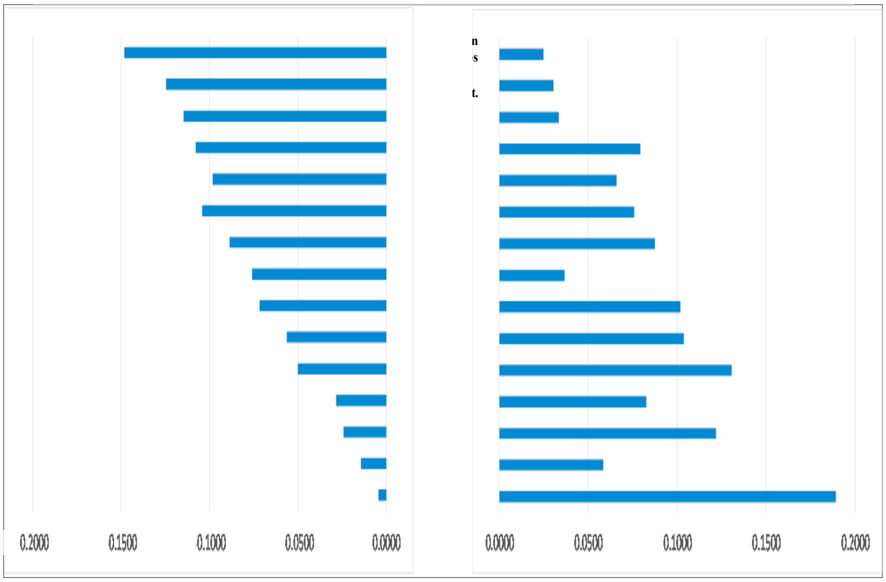

Fig. 3. Comparison of Case Study Results on Supply Chain Visibility Factors Prioritisation for Supply Chain Resilience.

The factors are based on their inclinations towards technology or supply chain relationships. Automation, dynamic capability, information management, information sharing, absorptive capability, context awareness, and information quality were more important for the DTP supply chain managers. Supply chain relationships, nature of management, resources, motives, and motives were ranked higher for the SCRP supply chain manager. Integration and connectivity, linkages, laws, policies, standards, and interoperability and connectivity were critical to both perspectives i.e. DTP and SCRP. The factors of automation and supply chain relationships show the most significant discrepancies between the two perspectives, and this shows the significance of considering differences among supply chain managers and their inclinations. These discrepancies can be explained through the role of the supply chain manager and their inclination to focus more on supply chain relationships between stakeholders (SCRP) or on automated processes (DTP).

Automation can help support the response in case of supply chain disruptions and is considered essential for supply chain redesign, notably following the COVID-19 pandemic. COVID-19 has increased the need for automation due to restrictions on the movement of people [29]. Automation can reduce the dependency on human resources through mechanisation (e.g. robotics, A.I., blockchain), and it is becoming essential to prepare for supply chain distributions in future instances [30,31]. The literature describes automation as a long-term supply chain adaptation rather than a short-term one due to the resources needed [30]. For resource constraints in SMEs, automation can be implemented to consider such constraints by adopting digital tools to streamline back-office processes and scaling up over time towards manufacturing and logistics automation (i.e. robotics). Information sharing, Information management, and information quality have also ranked highly related to the visibility of information throughout the chain and are more technology-oriented. Digital technologies that foster open, transparent information sharing might support the case company and other companies that lack information sharing compared to large companies. The dynamic capability has also been shown to be essential and may be built into a company to react quickly to supply chain disruptions and thus supports resilience through agility. It is also crucial in enhancing visibility through other factors like automation or enhanced information sharing.

Supply chain resilience can benefit through supply chain relationships employing communication, trust, commitment, cooperation, and transparency [32]. Supply chain relationships can create resilience through increased agility, flexibility, and redundancy, facilitating decision-making between supply chain stakeholders [33]. In some studies, supply chain relationships have outweighed the need for digitalisation [34], thus reflecting the possible comparative importance of the SCRP factor over the DTP factor. However, digital transformation can further support supply chain relationships through streamlining information and business processes [35].

Resources are required to acquire and maintain supply chain visibility, which is recognised by both DTP and SCRP managers. However, resources VIFs are ranked higher for the DTP supply chain manager, and this may be especially so for SMEs reflecting the size of Company X. Through enhanced levels of visibility, supply chain managers can prepare and be alert to potential disruptions and enhance resource orientation in supply chains [36]. Resources are crucial in SMEs due to the relatively low amount of mechanisation compared to larger companies, relying more on human resources. As SMEs develop through, for example, digitalisation, investments are increasingly important and may be seen as an adoption barrier, thus impacting technology support for visibility in the supply chain [37].

Interestingly, both the DTP and SRP supply chain managers recognised the importance of integration and connectivity. Integration and connectivity are closely related to data exchange between systems; for example, the integration of industry 4.0 technologies can help reduce disruption risk [38]. Digitalisation plays a vital role in supply chain integration towards resilience [39] through, for example, technologies that enable predictive capabilities [40]. This integration and connectivity also support the SCRP supply chain focus and may extend beyond the technology focus, and also consider the integration and connectivity between actors to enhance resilience [41]. The method can support managers as it is useful when prioritising visibility factors to support resilience in a supply chain. Based on the results, the approach also shows the differences between different managerial perspectives and the essential differences between the perspectives. Overall, there is perhaps a need to appropriately strike a good balance between the DTP and the SCRP perspectives when prioritising the VIFs.

5. Conclusion

This paper assessed visibility factors in an SME to support supply chain resilience. Supply chain visibility is essential to support the response to unforeseen risks and supply chain disruption, thus supporting resilience, and this has become an essential consideration over recent years in light of significant supply chain disruptions. Fourteen supply chain visibility factors were selected and prioritised through a Fuzzy Approach. Prioritisation took place for two respondent types: supply chain managers inclined towards digital technology perspectives and supply chain managers inclined more towards supply chain relationship perspectives (SCRP). Four main findings are; i) There are notable differences between the two perspectives within the prioritisation of factors, showing an important trend toward recognising managers' focus when conducting such prioritisations. ii) Supply chain relationships, nature of management, and resources were ranked highly for the SCRP supply chain manager. Supply chain relationships and motives are closely linked to people and resources and are an essential consideration for technology and human resources. iii) Automation, Information management, and Information sharing were important for the DTP supply chain managers. This could be expected as all three link closely towards digitalisation. iv) Resources are critical for supply chains to adapt to change quickly and prepare for distribution, as seen by the participants.

The case study approach and the adoption of Fuzzy Logic to gain insight into the prioritisation of supply chain visibility factors were appropriate and provided good insight. However, a fundamental limitation is that the factors may vary between companies, especially when comparing SMEs to prominent institutes. Future work can support these limitations through quantitative research or the analysis of more companies.

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