

# Uncertain Supply Chain Management

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## What are the obstacles hindering digital transformation for small and medium enterprise freight logistics service providers? An interpretive structural modeling approach

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### ABSTRACT

Digital Transformation (DT) allows logistics service providers (LSPs) to gain competitive advantages by reducing costs, and creating customer experience, innovation and efficiency. This paper proposes a systematic framework to analyse the obstacle factors hindering DT of Thailand small and medium enterprises freight LSPs. First, thirteen obstacles are identified through the extensive literature and validated by a panel of experts. Second, a nine-level hierarchical structure is determined based on Interpretive Structural Modelling to demonstrate the complex interrelationships among obstacle factors. Finally, thirteen obstacles are categorized regarding the driving and dependence power by employing Matrix Impact of Cross Multiplication Applied to Classification approach. The results indicate a lack of digital culture being the most important obstacle hindering DT, followed by lack of support and commitment from top management and lack of risk taking initiative. This finding could help LSPs who aim for DT to take appropriate steps to alleviate obstacles.

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## 1. Introduction

In recent years, the rapid advancement of digital technologies such as big data, Internet of Things, artificial intelligence, etc. has shaped the logistics service industry's competitive landscape. This has greatly affected the way freight logistics service providers (LSPs) firms conduct their business (Vendrell-Herrero et al., 2016; and Büyükközkcan & Göçer, 2018). To survive in a competitive environment, LSPs are forced to digitize (Hofmann & Osterwalder, 2017; Marchet et al., 2017). Digital transformation (DT) refers to the process of digital technologies integration into organizational business processes to improve business efficiency and create new delivery values for customers (Clohessy et al., 2017; Mathauer and Hofmann, 2019). DT has emerged as a key trend of modernization in the logistics sector of the economy. By 2025, the digital business in logistics is expected to grow by \$USD15 trillion (Ghezzi, & Cavallo, 2020). Preindl et al. (2020) recommended that LSPs should exploit the opportunities arising from DT by developing strategies, business models and cultures. Transforming digitally enables LSPs to increase efficiency and lower costs, improve traceability and flexibility, and enhance customer experience, as well as implement new business models (Calatayud et al., 2019; Attaran, 2020). Despite the numerous benefits of DT, many LSPs have failed to digitize as there are a number of obstacles that are embedded in their organizations. According to a recent study by Ivanov, et al. (2018), it is difficult for organizations to conduct DT processes because they have to adapt to the dynamic environment. Hess et al. (2016) supported that DT is a complex and uncertain process that poses many barriers to success. Many enterprises ignore their potentials for DT implementation because of facing different obstacle factors (Vial, 2019). Hence, in order to conquer them, digital organizations need to identify the obstacles involved and understand their nature and roots. Martinsuo and Luomaranta (2018) investigated that different characteristics of organizations will influence DT. Small and medium-sized enterprises (SMEs) confront more difficulty in DT than large firms due to a number of barriers (Cichosz et al., 2020). According to the study by Warner & Wäger (2019), most SMEs

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lack a plan to adopt new digital technologies because they think they are not ready to adapt to the DT paradigm. Previous researches have studied the barriers that hinder DT in supply chain (Cichosz et al., 2020; Agrawal et al., 2020), only a few studies have examined the context of freight logistics service providers particularly in SMEs. In addition, exploring the interrelationship among these barriers has not been fully explored. The present work attempts to fill the gaps by (i) identifying the significance of the DT hindrances facing by LSPs through extensive literature review, and (ii) discovering the interdependence of DT hindrances by applying interpretive structural modelling (ISM). An empirical study is conducted by using SMEs freight LSPs in Thailand as an empirical case study as most of them are lagging behind in DT. The finding of this study provides LSP managers and practitioners for SMEs to deeply understand and systematically resolve those obstacles in order to increase the rate of DT success.

The remainder of this paper is structured as follows: Section 2 presents literature review of obstacle factors to DT. The research framework is described in Section 3. Empirical case study is illustrated in Section 4. Section 5 provides the discussions of findings. Finally, conclusions are given in Section 6.

## 2. Literature review

The extensive literature was carried out through the accepted academic databases i.e. Web of Science, Science-Direct, Taylor & Francis and Emerald. Thirteen obstacle factors associated with DT are identified and described as follows:

### 2.1 Lack of adequate funding sources (O1)

DT requires a large investment in know-how and technology (Agrawal et al., 2020). Investing in digital technology upgrades carries a high risk and uncertain return on investment (Cichosz et al., 2020). Typically, SMEs logistics enterprises have insufficient financial resources and difficulties to obtain funds. A lack of adequate funds is also one of the major obstacles for SMEs to digitize (Karltopr, 2017).

### 2.2 Lack of digital culture (O2)

Digital culture refers to an organizational culture that embraces values and norms for adopting digital technology (Bughin, & Zeebroeck, 2017). Duerr et al. (2018) emphasized that digital culture is essential to DT of an organization. Therefore, there is a large requirement for DT to foster a digital culture that supports organizational changes. If LSPs have failed to develop a digital culture, any efforts for digital transformation will not be successful (Wokurka, 2017).

### 2.3 Lack of ICT infrastructure (O3)

The Information Communication Technology (ICT) infrastructure is one of the prerequisites required for digital transformation (Loonam et al., 2018). The success of the digital transformation relies on the availability of the ICT infrastructure, including telecommunication facilities, software and hardware (Kamble et al., 2018). Compared to large organizations, SMEs are slower to adopt new advanced technologies, mainly due to lacking ICT infrastructure. In addition, Vogelsang et al, (2019) reports that the lack of ICT infrastructure is a major obstacle for SMEs in many developing countries.

### 2.4 Lack of economic of scale /Small-scale business operation (O4)

Most SME LSPs with low services of volumes and operations may be reluctant to adopt new technology. They view that an investment in digital transformation is not as economies of scale. According to a study of Cichosz et al. (2020), the business operation scale is an important factor of the enterprises' involvement and decision making in acquiring new digital technologies. Also SMEs with fewer than 10 employees are less likely to use digital technologies than larger firms (MacGregor, 2004). The scope of business has a great influence on the adoption of digital technology.

### 2.5 Organization resistance (O5)

DT requires a significant change in the way organizations work. Traditionally, employees are familiar with the existing working system, so they may have a resistance to any changes in fear of learning new things (Vey et al., 2017). Employees also believe that digital transformation can pose a threat to their job security and result in job loss. One of the reasons for employee resistance is their inability to understand the potential benefits of digital technology (Lee & Lee, 2015).

### 2.6 Risk of cyber security and confidentiality (O6)

A study by Vaidya et al. (2018) found that many enterprises declined to accept digital businesses due to some concerns on security issues and a lack of confidence in a digital business setting. SMEs may encounter security issues, including payment security, cyber-attack, privacy and confidentiality of information (Colicchia et al., 2019). Maktadir et al. (2018) identified that the fragmentation of cybersecurity standards is one of main barriers to DT.

### 2.7 Lack of digital skills and talent (O7)

Hiring and developing employees with digital skills and talent are vital to organizations, which have driven toward digital transformation. It is broadly recognized that a qualified digital skilled workforce is a valuable and rare asset in a labor

market (Vogelsang et al., 2019). SMEs are unable to hire employees with digital skills due to weak financial status (Liboni et al., 2019). Davis et al. (2015) also emphasized that lacking digital skills and talent is one of major obstacles to digital transformation.

### *2.8 Lack of digital business model (O8)*

Before stepping into digital, it is essential for firms to develop a digital business model as it is a value creation model through the development of customer benefits via digital technology (Loonam et al., 2018). The digital business model provides new ideas for commercial products and services based on a predetermined business model (Lee & Lee, 2015). Firms should continually transform their digital business models in response to changes in business environments such as technological innovations, socioeconomic trends and industrial regulations (Frank et al., 2019). Despite the importance of the digital business model, prior research reported that many organizations especially in SMEs are unable to develop it (Lee & Lee, 2015). Failure to develop digital business model, firms cannot take advantages from DT (Sarvari et al., 2018).

### *2.9 Lack of supply chain integration between partners (O9)*

Since DT requires information sharing and joint data interchange on both suppliers and (Büyüközkan, & F. Göçer, 2018). Organizations need to establish supply chain integration among their supply chain partners (Crittenden et al., 2019). Ghobakhloo (2018) supported that fostering trust, openness, willingness to collaborate, leverage digital technology and strengthen supply chain integration are essential for SMEs to perform digital transformation. Singh et al. (2018) emphasized that most SMEs face obstacles in forming partnerships for supply chain integration both internal and external value chains due to knowledge incompatibility, partner geographic location, high transaction cost and organizational cultural differences. Hence, a failure to develop supply chain integration is a remarkable barrier to digital transformation.

### *2.10 High initial investment costs (O10)*

DT requires a significant investment in people, processes, technologies, and infrastructure for both enterprises and supply chain parties (Agrawal et al., 2020). SMEs are often hesitant to adopt digital technology due to high initial investment costs and potential risks posed by the immature technology (Hahn, 2020). Giotopoulos et al. (2017) emphasized that high initial investment costs are a major barrier to digital transformation among SMEs.

### *2.11 Lack of support and commitment from top management (O11)*

Previous literature revealed that degrees of top management commitment and support are positively influenced by the adoption of information technologies in organizations (Liang et al., 2007; Gangwar et al., 2015). The adoption of innovative technology has been transformed from top to bottom of the organizations (Gangwar et al., 2015). Top management should understand the benefits of digital technology adoption to the future of organizational competitive advantages and performances (Sony & Naik, 2019). They should also play a significant role in DT activities by establishing strategic plannings, allocating adequate resources, providing the essential facilities and encouraging employees (Oliveira et al., 2019). In addition, Büyüközkan & Göçer (2018) stated that most SMEs are lacking strong support from top management when implementing information technologies.

### *2.12 Insufficient support from the government (O12)*

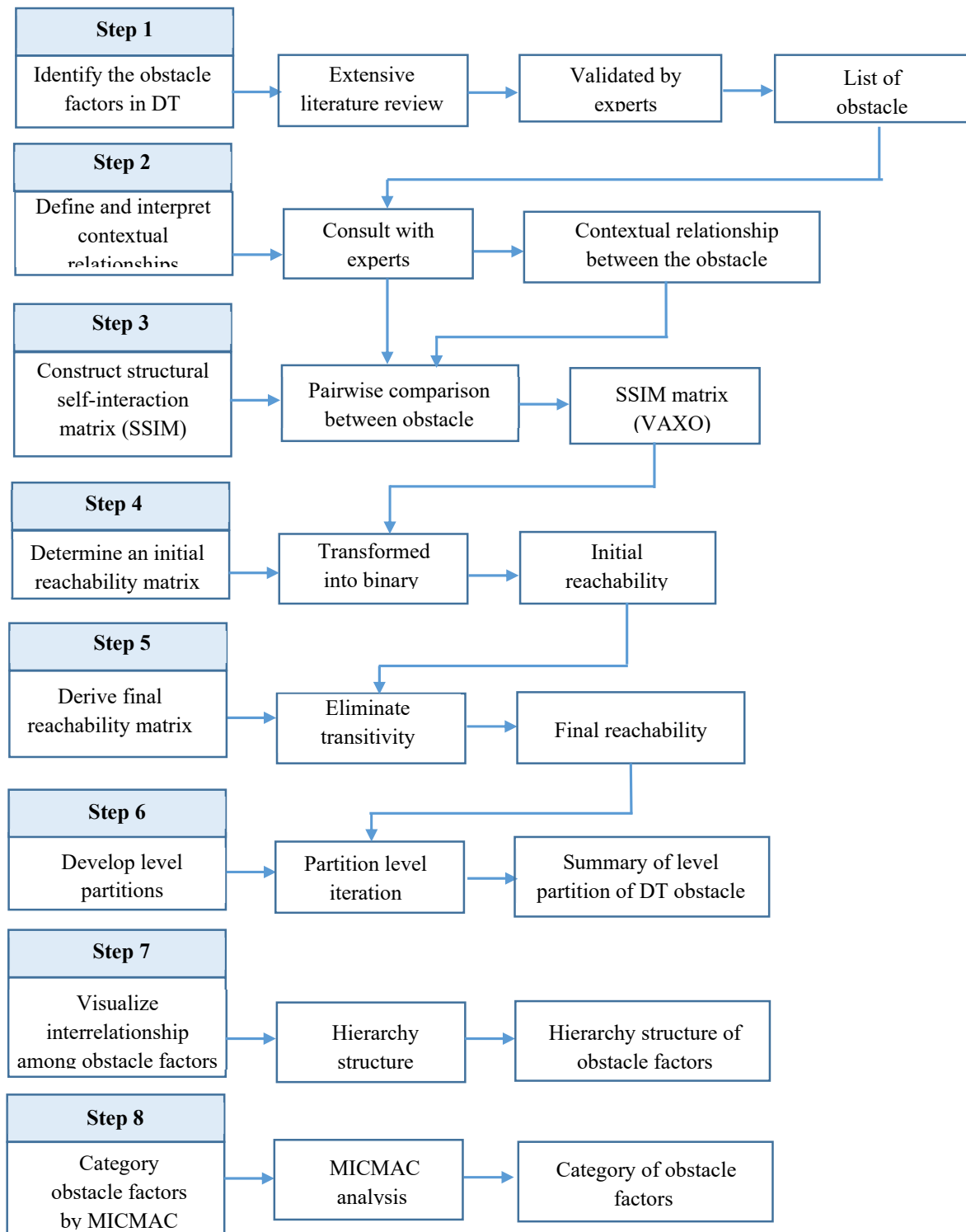
Some previous studies stated that the government plays several key roles to promote and accelerate DT for SMEs (Cichosz et al., 2020; Agrawal et al., 2020). The roles of government are such as raising awareness, enhancing digital skills of workers, assisting SMEs to overcome financial difficulties, improving laws to support nationwide DT, rewarding for practices and coordinating with industries to set up digital security guidelines (Kamble et al., 2018).

### *2.13 Lack of risk taking initiative (O13)*

When organizations enter DT, they go into unfamiliar processes and require drastic changes in their business models. Several SMEs view DT as complex, high investment and operating costs, and uncertain outcomes (Kamble et al., 2018). SMEs would encounter numerous risks associated with DT such as organization resistance, uncertain market demand, technology disruption and ambiguous return on investment (ROI) (Agrawal et al., 2020). Martinsuo & Luomaranta (2018) noted that SMEs usually reluctance to deal with uncertain business circumstances. Hence, the lack of risk taking initiative is an important obstacle factor in DT for SMEs.

## **3. Research framework**

This study proposes an eight-step framework based on ISM procedure, as displayed in Figure 1. The research framework consists of (1) identify and validate the obstacle factors in DT, (2) define and interpret contextual relationships, (3) construct structural self-interaction matrix (SSIM), (4) determine an initial reachability matrix, (5) derive final reachability matrix, (6) develop level partitions, (7) visualize interrelationship among obstacle factors, and (8) category obstacle factors by Matrix Impact of Cross Multiplication Applied to Classification (MICMAC).



**Fig. 1.** The proposed framework based on ISM procedure

## 4. Empirical Study

### 4.1 Background

Thailand is taking steps to drive DT and harness innovation into a state-of-the-art economic powerhouse. The country's digital path is promoted under the "Thailand 4.0" economics scheme, which focuses on significant advancements and digital improvements to drive "added value" for products and services. The ultimate goal of the government is to develop Thailand

as a digital hub of ASEAN. Under Thailand 4.0 model, the logistics sector is one of the targeted industries that Thai government plans to facilitate. The logistics sector plays an important role in the economic development of Thailand by connecting firms' business opportunities with both domestic and international markets.

In 2019, Thai logistics market had a total value of USD 46.30 billion. It is projected to continue growing up to USD 64.4 billion by 2020 and USD 82.7 billion by 2022. Thai logistics sector is dominated by SMEs freight logistics service providers, which accounts for 57.6% of total logistics revenues in 2019. They are considered as the backbone of the logistics sector of Thailand. In the context of DT, many large freight logistics companies in Thailand have already adopted the advanced digital technology in their businesses. However, the number of Thai SMEs logistics service providers in DT is limited. Most of them are still lagging behind in DT due to various obstacle factors. Hence, a clear understanding of these obstacles and interrelationships is a good chance to initiate the appropriate course of actions.

#### 4.2 ISM application

ISM was first introduced by Warfield (1974) to explore the interrelationship among factors in complicated socioeconomic systems (Samantra et al., 2016). The concept of ISM is that the complex system can be decomposed into different subsystems and then converted into hierarchical multi-level structure. This approach is enabled to transform unstructured problems into visible and articulated one. Recently, ISM has been widely employed to study supply chain and logistics contexts such as barriers of green textile supply chain management (Majumdar & Sinha, 2018), supply chain collaboration on green innovation performance (Yang & Lin, 2020), analysis of supply chain sustainability with supply chain complexity (Chand et al., 2020). The ISM procedure to analyze the obstacle factors that hinder DT is described as follows:

##### 4.2.1 To identify the obstacle factors

Based on thirteen obstacle factors as described in DT in Section 2, seven qualified experts, comprised of three managerial staffs from different LSPs firms who successfully deployed DT, two academicians from relevant fields, one manager from a logistics consulting firm and one vice president from freight logistics association of Thailand, were invited to review the list of obstacle factors. The details and qualifications of the experts are illustrated in Appendix A. After several rounds of discussion, thirteen obstacle factors were validated and summarized to use in this study, as exhibited in Table 1.

**Table 1**

Summarizes the obstacle factors of DT in Thai SMEs freight logistics service providers

Code	Obstacle factors
$O_1$	Lack of adequate funding sources
$O_2$	Lack of digital culture
$O_3$	Lack of ICT infrastructure
$O_4$	Lack of economic of scale /Small-scale business operation
$O_5$	Organization resistance
$O_6$	Risk of cyber security and confidentiality
$O_7$	Lack of digital skills and talent
$O_8$	Lack of digital business model
$O_9$	Lack of supply chain integration between partners
$O_{10}$	High initial investment costs
$O_{11}$	Lack of support and commitment from top management
$O_{12}$	Insufficient support from the government
$O_{13}$	Lack of risk taking initiative

##### 4.2.2 To define and interpret contextual relationships

In consultation with the experts, a contextual relationship between the obstacle factors is defined. For example, if the obstacle factor  $O_1$  influences  $O_2$  then it can be interpreted as " $O_1$  leads to  $O_2$ ".

##### 4.2.3 To construct structural self-interaction matrix (SSIM)

Given the interpretation of contextual relationships in section 4.2.2, the experts provide a direction of relationship between two obstacle factors ( $i$  and  $j$ ) by means of a pairwise comparison. Four symbols are used to express the direction of relationship between hindrance factors ( $i$  and  $j$ ): V: obstacle factor  $i$  leads to hindrance factor  $j$  A: obstacle factor  $j$  leads to hindrance factor  $i$  X: obstacle factor  $i$  and  $j$  are mutually leading O: obstacle factor  $i$  and  $j$  have no relation After the acquired data are gathered, SSIM of DT obstacles is constructed as seen in Table 2.

##### 4.2.4 To determine initial reachability matrix

The initial reachability matrix is determined by transform SSIM into the binary matrix by replacing V, A, X, O with 1 and 0, based on a case-by-case basis, as follows: Case I: If the element ( $i, j$ ) in SSIM is V then substitution the ( $i, j$ ) and ( $j, i$ ) with 1 and 0, respectively. Case II: If the element ( $i, j$ ) in SSIM is A then substitution the ( $i, j$ ) and ( $j, i$ ) with 0 and 1, respectively. Case III: If the element ( $i, j$ ) in SSIM is X then substitution both ( $i, j$ ) and ( $j, i$ ) with 1. Case IV: If the element ( $i, j$ ) in SSIM is O then substitution both ( $i, j$ ) and ( $j, i$ ) with 0. The initial reachability matrix of DT obstacle factors for Thai SMEs freight LSPs is shown in Table 3.

**Table 2**

Structured self-interaction matrix (SSIM) of DT obstacle factors

Code	O <sub>13</sub>	O <sub>12</sub>	O <sub>11</sub>	O <sub>10</sub>	O <sub>9</sub>	O <sub>8</sub>	O <sub>7</sub>	O <sub>6</sub>	O <sub>5</sub>	O <sub>4</sub>	O <sub>3</sub>	O <sub>2</sub>	O <sub>1</sub>
O <sub>1</sub>	O	O	A	V	V	X	V	V	O	X	V	O	
O <sub>2</sub>	V	O	A	O	V	V	V	V	V	O	V		
O <sub>3</sub>	A	A	A	A	V	A	X	V	A	A			
O <sub>4</sub>	A	A	A	A	V	A	V	V	A				
O <sub>5</sub>	A	O	A	A	V	A	X	O					
O <sub>6</sub>	A	A	A	A	V	A	A						
O <sub>7</sub>	A	A	A	A	V	A							
O <sub>8</sub>	A	A	A	A	V								
O <sub>9</sub>	A	A	A	A									
O <sub>10</sub>	A	A	A										
O <sub>11</sub>	A	V											
O <sub>12</sub>	O												
O <sub>13</sub>													

**Table 3**

Initial reachability matrix of DT obstacle factors

Code	O <sub>1</sub>	O <sub>2</sub>	O <sub>3</sub>	O <sub>4</sub>	O <sub>5</sub>	O <sub>6</sub>	O <sub>7</sub>	O <sub>8</sub>	O <sub>9</sub>	O <sub>10</sub>	O <sub>11</sub>	O <sub>12</sub>	O <sub>13</sub>
O <sub>1</sub>	1	0	1	1	0	1	1	1	1	1	0	0	0
O <sub>2</sub>	0	1	1	0	1	1	1	1	1	0	1	0	1
O <sub>3</sub>	0	0	1	0	0	1	1	0	1	0	0	0	0
O <sub>4</sub>	1	0	1	1	0	1	1	0	1	0	0	0	0
O <sub>5</sub>	0	0	1	1	1	0	1	0	1	0	0	0	0
O <sub>6</sub>	0	0	0	0	0	1	0	0	1	0	0	0	0
O <sub>7</sub>	0	0	1	0	1	1	1	0	1	0	0	0	0
O <sub>8</sub>	1	0	1	1	1	1	1	1	1	0	0	0	0
O <sub>9</sub>	0	0	0	0	0	0	0	0	1	0	0	0	0
O <sub>10</sub>	0	0	1	1	1	1	1	1	1	1	0	0	0
O <sub>11</sub>	1	1	1	1	1	1	1	1	1	1	1	1	0
O <sub>12</sub>	0	0	1	1	0	1	1	1	1	1	0	1	0
O <sub>13</sub>	0	0	1	1	1	1	1	1	1	1	1	0	1

#### 4.2.5 To derive final reachability matrix

The final reachability matrix is then derived by taking into consideration the transitivity. Based on transitivity principle, if a hindrance factor 'i' leads to 'j' and 'j' leads to 'k' then it is imperative that 'i' leads to 'k'. The final reachability matrix of DT obstacle factors for Thai SMEs freight logistics service providers is illustrated in Table 4, wherein transitivity is marked with 1\*.

#### 4.2.6 To develop level partitions

According to the final reachability matrix, the reachability set ( $RS_i$ ) and antecedent set ( $AS_i$ ) are developed.  $RS_i$  composes of hindrance factors 'i' itself including other factors with a value of 1 in each row, whereas  $AS_i$  composes of hindrance factors 'i' itself including with a value of 1 in each column. Thereafter, the intersection of  $RS_i$  and  $AS_i$  ( $RS_i \cap AS_i$ ) is determined. By comparison  $RS_i$  and ( $RS_i \cap AS_i$ ), if the factors within  $RS_i$  and ( $RS_i \cap AS_i$ ) are equal, then they are assigned to the top-level (level I) in the hierarchy structure. Factors in level I mean that they would not lead other factors above their own levels. After obtaining level I, factors in level I are removed. To obtain the subsequent level partitions, these corresponding iterations are performed until all remaining factors are allocated to the respective levels. In this paper, thirteen obstacle factors are partitioned through nine iterations, which are summarized in Table 5.

**Table 4**

Final reachability matrix of DT obstacles

Code	O <sub>1</sub>	O <sub>2</sub>	O <sub>3</sub>	O <sub>4</sub>	O <sub>5</sub>	O <sub>6</sub>	O <sub>7</sub>	O <sub>8</sub>	O <sub>9</sub>	O <sub>10</sub>	O <sub>11</sub>	O <sub>12</sub>	O <sub>13</sub>	Driving power
O <sub>1</sub>	1	0	1	1	0	1	1	1	1	1	0	0	0	8
O <sub>2</sub>	1*	1	1	1*	1	1	1	1	1	1*	1	1*	1	13
O <sub>3</sub>	0	0	1	0	1*	1	1	0	1	0	0	0	0	5
O <sub>4</sub>	1	0	1	1	1*	1	1	0	1	0	0	0	0	7
O <sub>5</sub>	1*	0	1	1	1	1*	1	0	1	0	0	0	0	7
O <sub>6</sub>	0	0	0	0	0	1	0	0	1	0	0	0	0	2
O <sub>7</sub>	1*	0	1	1*	1	1	1	1*	1	1*	0	0	0	9
O <sub>8</sub>	1	0	1	1	1	1	1	1	1	1*	0	0	0	9
O <sub>9</sub>	0	0	0	0	0	0	0	0	1	0	0	0	0	1
O <sub>10</sub>	1*	0	1	1	1	1	1	1	1	1	0	0	0	9
O <sub>11</sub>	1	1	1	1	1	1	1	1	1	1	1	1	1*	13
O <sub>12</sub>	1*	0	1	1	1*	1	1	1	1	1	0	1	0	10
O <sub>13</sub>	1*	1*	1	1	1	1	1	1	1	1	1*	1	1	13
Dependence Power	10	3	11	10	10	12	11	8	13	8	3	4	3	

**Table 5**  
Summary of level partition of DT obstacle factors

Code	Description	Reachability Set $RS_i$	Antecedent Set $AS_i$	Intersection set ( $RS_i \cap AS_i$ ) $AS_i$	Level
O <sub>9</sub>	Lack of supply chain integration between partners	{O <sub>9</sub> }	{O <sub>1</sub> ,O <sub>2</sub> ,O <sub>3</sub> ,O <sub>4</sub> ,O <sub>5</sub> ,O <sub>6</sub> ,O <sub>7</sub> ,O <sub>8</sub> ,O <sub>9</sub> ,O <sub>10</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>9</sub> }	I
O <sub>6</sub>	Risk of cyber security and confidentiality	{O <sub>6</sub> }	{O <sub>1</sub> ,O <sub>2</sub> ,O <sub>3</sub> ,O <sub>4</sub> ,O <sub>5</sub> ,O <sub>6</sub> ,O <sub>7</sub> ,O <sub>8</sub> ,O <sub>10</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>6</sub> }	II
O <sub>7</sub>	Lack of digital skills and talent	{O <sub>1</sub> ,O <sub>3</sub> ,O <sub>4</sub> ,O <sub>5</sub> ,O <sub>6</sub> ,O <sub>7</sub> ,O <sub>8</sub> ,O <sub>10</sub> }	{O <sub>1</sub> ,O <sub>2</sub> ,O <sub>3</sub> ,O <sub>4</sub> ,O <sub>5</sub> ,O <sub>7</sub> ,O <sub>8</sub> ,O <sub>10</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>1</sub> ,O <sub>3</sub> ,O <sub>4</sub> ,O <sub>5</sub> ,O <sub>6</sub> ,O <sub>7</sub> ,O <sub>8</sub> ,O <sub>10</sub> }	II
O <sub>3</sub>	Lack of ICT infrastructure	{O <sub>3</sub> ,O <sub>5</sub> }	{O <sub>1</sub> ,O <sub>2</sub> ,O <sub>3</sub> ,O <sub>4</sub> ,O <sub>5</sub> ,O <sub>8</sub> ,O <sub>10</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>3</sub> ,O <sub>5</sub> }	III
O <sub>1</sub>	Lack of adequate funding sources	{O <sub>1</sub> ,O <sub>4</sub> ,O <sub>8</sub> ,O <sub>10</sub> }	{O <sub>1</sub> ,O <sub>2</sub> ,O <sub>4</sub> ,O <sub>5</sub> ,O <sub>8</sub> ,O <sub>10</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>1</sub> ,O <sub>4</sub> ,O <sub>8</sub> ,O <sub>10</sub> }	IV
O <sub>4</sub>	Lack of economic of scale /Small-scale business operation	{O <sub>1</sub> ,O <sub>4</sub> ,O <sub>5</sub> }	{O <sub>1</sub> ,O <sub>2</sub> ,O <sub>4</sub> ,O <sub>5</sub> ,O <sub>8</sub> ,O <sub>10</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>1</sub> ,O <sub>4</sub> ,O <sub>5</sub> }	IV
O <sub>5</sub>	Organization resistance	{O <sub>5</sub> }	{O <sub>2</sub> ,O <sub>5</sub> ,O <sub>8</sub> ,O <sub>10</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>5</sub> }	V
O <sub>8</sub>	Lack of digital business model	{O <sub>8</sub> ,O <sub>10</sub> }	{O <sub>2</sub> ,O <sub>8</sub> ,O <sub>10</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>8</sub> ,O <sub>10</sub> }	VI
O <sub>10</sub>	High initial investment costs	{O <sub>8</sub> ,O <sub>10</sub> }	{O <sub>2</sub> ,O <sub>8</sub> ,O <sub>10</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>8</sub> ,O <sub>10</sub> }	VI
O <sub>12</sub>	Insufficient support from the government	{O <sub>12</sub> }	{O <sub>2</sub> ,O <sub>11</sub> ,O <sub>12</sub> ,O <sub>13</sub> }	{O <sub>12</sub> }	VII
O <sub>11</sub>	Lack of support and commitment from top management	{O <sub>2</sub> ,O <sub>11</sub> ,O <sub>13</sub> }	{O <sub>2</sub> ,O <sub>11</sub> ,O <sub>13</sub> }	{O <sub>2</sub> ,O <sub>11</sub> ,O <sub>13</sub> }	VIII
O <sub>13</sub>	Lack of risk taking initiative	{O <sub>2</sub> ,O <sub>11</sub> ,O <sub>13</sub> }	{O <sub>2</sub> ,O <sub>11</sub> ,O <sub>13</sub> }	{O <sub>2</sub> ,O <sub>11</sub> ,O <sub>13</sub> }	VIII
O <sub>2</sub>	Lack of digital culture	{O <sub>2</sub> }	{O <sub>2</sub> }	{O <sub>2</sub> }	IX

#### 4.2.7 To visualize the interrelationship among obstacle factors

Based on the results in Table 5, the thirteen obstacle factors are plotted in the diagram to visualize their interrelationships, as depicted in Fig. 2. The arrow pointing from factor  $i$  to factor  $j$  indicates factor  $i$  can lead to factor  $j$  and a two-way arrow indicates interplay. In addition, each obstacle factor at higher level in hierarchical structure is directly affected by at least one obstacle factor at the next adjacent lower level and indirectly affected by the remaining of other lower-level obstacle factors. In this study, the thirteen obstacle factors are separated into nine levels of the ISM hierarchical structure as follows:

Level I: lack of supply chain integration between partners (O<sub>9</sub>) is located at the top of the structure model. This obstacle is led by the twelve remaining obstacles.

Level II: include risk of cyber security and confidentiality (O<sub>6</sub>) and lack of digital skills and talent (O<sub>7</sub>), these obstacles directly lead to lack of supply chain integration between partners (O<sub>9</sub>). In addition, lack of digital skills and talent (O<sub>7</sub>) also leads to risk of cyber security and confidentiality (O<sub>6</sub>).

Level III: lack of ICT infrastructure (O<sub>3</sub>). It directly leads to risk of cyber security and confidentiality (O<sub>6</sub>) and lack of digital skills and talent (O<sub>7</sub>).

Level IV: comprises lack of adequate funding sources (O<sub>1</sub>) and lack of economy of scale (O<sub>4</sub>), these obstacles directly lead to lack of ICT infrastructure (O<sub>3</sub>). Both obstacles mutually lead to each other. Level V: organization resistance (O<sub>5</sub>), this obstacle directly leads to lack of adequate funding sources (O<sub>1</sub>) and lack of economy of scale (O<sub>4</sub>).

Level VI: consists of lack of digital business model (O<sub>8</sub>) and high initial investment costs (O<sub>10</sub>), these obstacles directly lead to organization resistance (O<sub>5</sub>). Both obstacles mutually lead to each other.

Level VII: the insufficient support from government (O<sub>12</sub>) directly leads to lack of digital business model (O<sub>8</sub>) and high initial investment costs (O<sub>10</sub>).

Level VIII: contains lack of support and commitment from top management (O<sub>11</sub>) and lack of risk taking initiative (O<sub>13</sub>).

Level IX: lack of support and commitment from top management (O<sub>2</sub>) positions at the bottom of hierarchy structure. This obstacle directly leads to lack of support and commitment from top management (O<sub>11</sub>) and lack of risk taking initiative (O<sub>13</sub>).

#### 4.2.8 To categorize obstacle factors by MICMAC

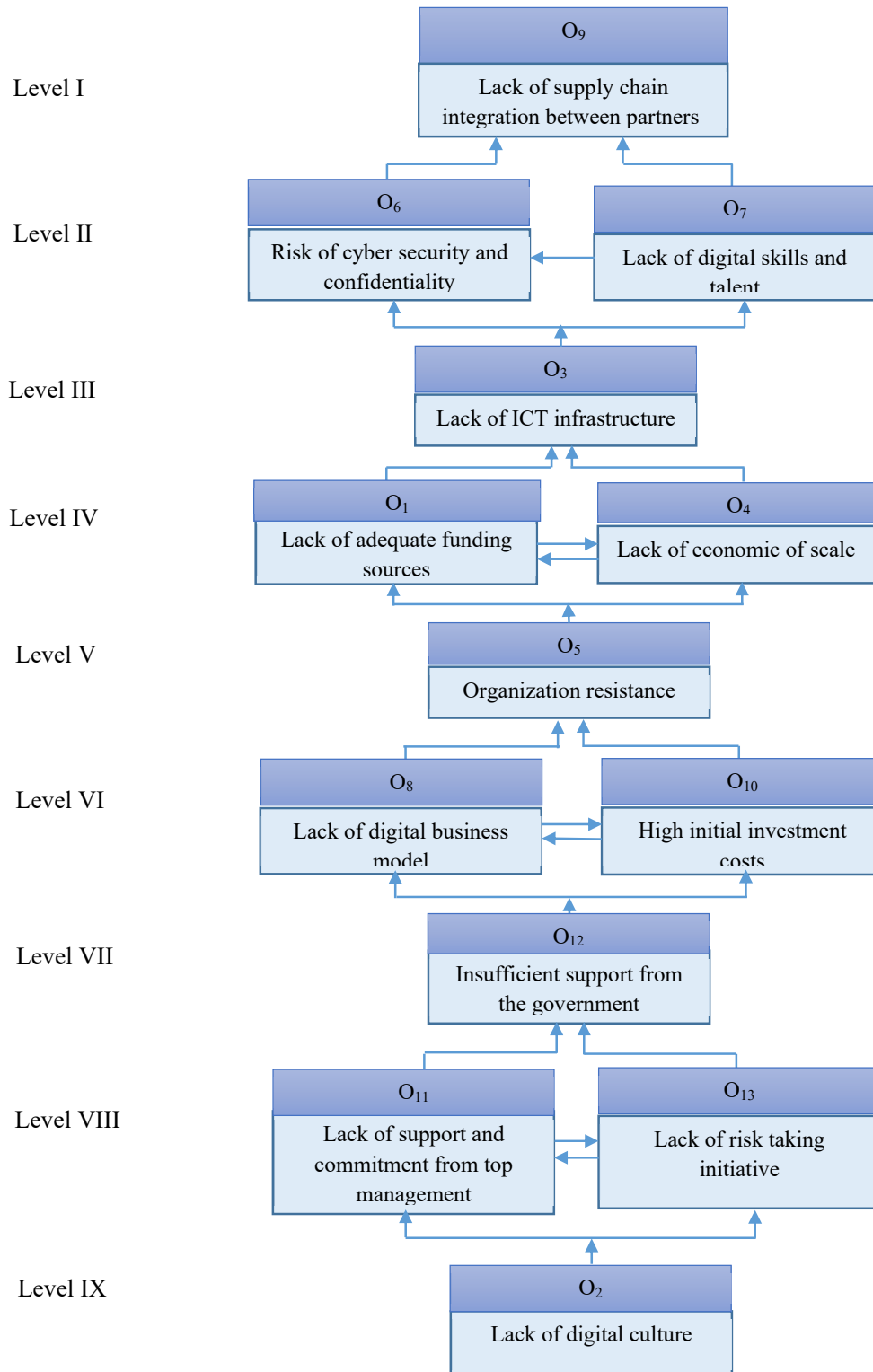
By using the final reachability matrix presented in Table 5, MICMAC is applied to category the thirteen obstacle factors into four groups. The steps of MICMAC are described as follows:

a) To calculate the driving power of each obstacle factor by summarizing all element values in the corresponding row of the final reachability matrix, as shown in Table 5.

b) To calculate the dependence power of each obstacle factor by summarizing all element values in the corresponding column of the final reachability matrix, as shown in Table 5.

c) To categorize the thirteen obstacle factors into four different groups regarding their driving and dependence powers, as illustrated in Table 6.

d) To plot the thirteen obstacle factors on MICMAC diagram with the respect to their association driving and dependence powers. In this diagram, the driving power is shown as the horizontal axis, and the dependent power is shown as the vertical axis. The positions of thirteen obstacle factors in MICMAC diagram are illustrated in Fig. 3.



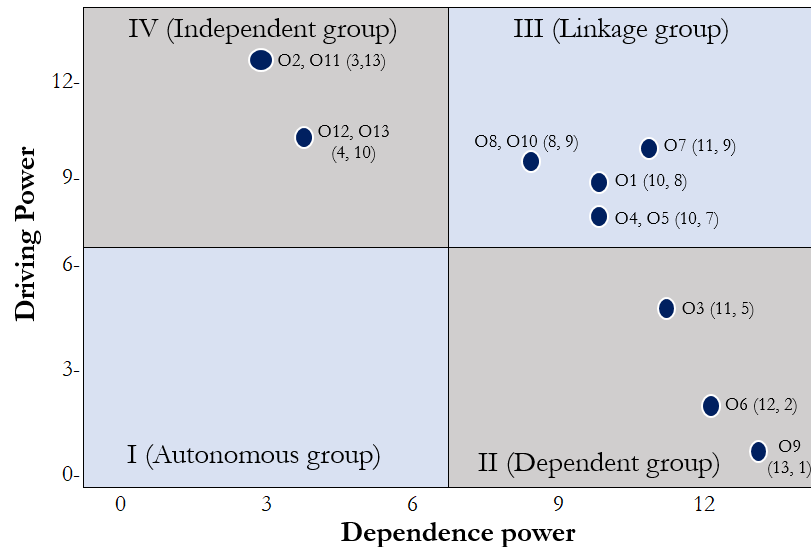
**Fig. 2.** The interrelationship among obstacle factors



**Table 6**

The classification of barriers factors according to driving and dependence power

Group	Description	Obstacle factors
Group I: Autonomous factors	Factors within this group are weak drives and weak dependence power. It can be interpreted that these factors are somewhat disconnected from the system.	None
Group II: Dependent factors	Factors within this group are weak driving and strong dependence power.	O <sub>3</sub> , O <sub>6</sub> , O <sub>9</sub>
Group III: Linkage factors	Factors within this group are strong driving and dependence power. It can be interpreted that these factors are quite unstable and that any action on them will have an impact on others and their self-feedback.	O <sub>1</sub> , O <sub>4</sub> , O <sub>5</sub> , O <sub>7</sub> , O <sub>8</sub> , O <sub>10</sub>
Group IV: Independent factors	Factors within this group are strong driving and weak dependence power.	O <sub>2</sub> , O <sub>11</sub> , O <sub>12</sub> , O <sub>13</sub>

**Fig. 3.** The positions of thirteen obstacle factors in the MICMAC diagram

## 5. Discussion

According to Fig. 2, the obstacle factor namely lacking supply chain integration (O<sub>9</sub>) is at the top level of hierarchy structure (Level IX), indicating that this obstacle factor is led by the remaining twelve obstacle factors at the lower levels. It can be seen that the lack of digital culture (O<sub>2</sub>) is at the lowest level (level IX), followed by lack of support and commitment from top management (O<sub>11</sub>) and lack of risk taking initiative (O<sub>13</sub>) are at level VIII. This implies that these are the three most significant obstacle factors which hinders the DT among SMEs freight logistics service providers in the case of Thailand. This present work reveals that lack of digital culture (O<sub>2</sub>) is the first most important. This result is supported by Buvat et al. (2018), who conducted the survey from 340 SMEs logistics service companies in Europe. Their survey reported that 62% of respondents viewed the lack of digital culture as the number one hindrance to DT. This study suggests that Thai SMEs logistics service providers who aim for DT should pay rigorous attention to addressing the lack of digital culture in their organizations. Also, organizations must promote a digital culture by sharing digital strategy, developing digital mindset at all organizational levels, creating a digital working environment before they go digital (Haffke et al., 2017). Next, lack of support and commitment from top management (O<sub>11</sub>) and a lack of risk taking initiative (O<sub>13</sub>) are the two most significant obstacle barriers, and lead to each other. The findings are consistent with previous studies. Büyüközkan & Göçer (2018) stressed that top management plays a key role in capturing logistics market trends, detecting and seizing technology opportunities and translating them into business plans. Top management should provide concerned stakeholders a clear vision of DT vision that directs employees, business partners on the DT path (Oliveira et al., 2019). In line with Sony & Naik (2019), top management should take an active role in inspiring and motivating employees at all levels to be actively involved in DT which can reduce organizational resistance. As mentioned earlier, DT is a complex, ambiguous and uncertain process that requires significant changes in an organization. Therefore, organizations, attempting to move toward DT, need the support and commitments from top management in terms of risk taking initiatives. The results of MICMAC analysis depicted in Figure 3, found that there are no obstacle factors in the autonomous group. It means that there is an interrelationship among the obstacle factors discussed in this study. Lack of ICT infrastructure (O<sub>3</sub>), risk of cyber security and confidentiality (O<sub>6</sub>), and lack of supply chain integration between partners (O<sub>9</sub>) are dependent groups. These obstacle factors have low driving powers but high dependence powers. Therefore, Thai SMEs freight LSPs should place low priority

in addressing these obstacle factors because they can be easily influenced by other factors. Next, lack of adequate funding sources ( $O_1$ ), lack of economy of scale, organization resistance ( $O_5$ ), lack of digital skills and talent ( $O_7$ ), lack of digital business model ( $O_8$ ) and high initial investment costs ( $O_{10}$ ) are in the linkage group. These obstacle factors have high driving and dependent power, meaning that any action on these obstacle factors can affect others and also feedback among themselves (Ali et al., 2018). Also, these obstacle factors need to be carefully managed and monitored (Jha & Devaya, 2008). Finally, lack of digital culture ( $O_2$ ), lack of support and commitment from top management ( $O_{11}$ ), insufficient support from the government ( $O_{12}$ ) and lack of risk taking initiative ( $O_{13}$ ) presents in the independent group with high driving and low dependence power. These obstacle factors can be considered as the major root cause in DT as they can highly influence other factors and are less to be influenced by other factors. In order to succeed in DT, Thai SMEs LSPs should place an emphasis on eliminating these obstacle factors since the effective alleviation of these obstacle factors can lead to mitigate other obstacles. It is worth to note that all obstacle factors of the bottom levels are in the independent group. And the obstacle factors of the top levels are in the dependent group. This means that there are consistent results between ISM and MICMAC.

## 6. Conclusion, limitations and future research

DT requires an enormous investment, time and effort as well as managing change in large corporations. There are numerous obstacle factors with hindering DT. Organizations may encounter the difficulties in managing these obstacles simultaneously. Therefore, the organizations need to understand “what obstacles that are hindering DT; how is the interrelationship and interplay among obstacles; and what is the most important obstacle that requires more attention”. This study builds on knowledge by providing an in-depth understanding of DT obstacles in Thai SMEs logistics service providers. First, the thirteen DT obstacle factors are identified through extensive literature review and validated by a panel of experts. Second, the interrelationship among thirteen DT obstacle factors has been determined and developed a hierarchy structure model by applying ISM approach.

Major outcomes of ISM are (i) thirteen obstacle factors fall into nine levels, and (ii) the obstacles factor that located in lowest level (level IX) namely “lack of digital culture” being as the most important factor followed by “lack of support and commitment from top management” and “lack of risk taking initiative”, respectively. Finally, the thirteen obstacle factors are divided into four groups based on driving and dependence power using the MICMAC method.

The results of MICMAC highlight that the crucial obstacle factors hinder DT are independent groups including lack of digital culture, lack of support and commitment from top management, insufficient support from the government and lack of risk taking initiative. Hence, the efficient actions to alleviate these factors can help Thai SMEs logistics service providers achieve great success in DT. While this research makes significant contributions, there are some limitations that should be addressed. One limitation is the scope of this study, which was conducted only in the context of Thai SMEs logistics service providers. Thus, future research should expand the framework of this paper to make comparisons between Thai logistics service providers and multinational companies. Another limitation is that ISM cannot demonstrate the strength of the interrelationship between obstacle factors. It is suggested that future studies may apply structural equation modelling (SEM) or decision making trial and evaluation laboratory (DEMATEL) for further analysis.

## References

- Agrawal, P., Narain, R., & Ullah, I. (2020). Analysis of barriers in implementation of digital transformation of supply chain using interpretive structural modelling approach. *Journal of Modelling in Management*, 15(1), 297-317.
- Ali, S. M., Arafin, A., Moktadir, M. A., Rahman, T., & Zahan, N. (2018). Barriers to reverse logistics in the computer supply chain using interpretive structural model. *Global Journal of Flexible Systems Management*, 19(1), 53-68.
- Attaran, M. (2020). Digital technology enablers and their implications for supply chain management. *Supply Chain Forum: An International Journal*, 21(3), 158-172.
- Bughin, J., & van Zeebroeck, N. (2017). The best response to digital disruption. *MIT Sloan Management Review*, 58(4), 80-86.
- Buvat, J., Solis, B., Crummenerl, C., Aboud, C., Kar, K., Aoufi, H. E., & Sengupta, A. (2018). *The Digital Culture Challenge: Closing the Employee-Leadership Gap*. Capgemini Digital Transformation Institute.
- Büyükożkan, G., & Göçer, F. (2018). Digital supply chain: literature review and a proposed framework for future research. *Computers in Industry*, 97, 157-177.
- Calatayud, A., Mangan, J., & Christopher, M. (2019). The self-thinking supply chain. *Supply Chain Management: An International Journal*, 24(1), 22-38.
- Chand, P., Thakkar, J. J., & Ghosh, K. K. (2020). Analysis of supply chain sustainability with supply chain complexity, inter-relationship study using delphi and interpretive structural modeling for Indian mining and earthmoving machinery industry. *Resources Policy*, 68, 101726. doi.org/10.1016/j.resourpol.2020.101726.
- Cichosz, M., Wallenburg, C. M., & Knemeyer, A. M. (2020). Digital transformation at logistics service providers: barriers, success factors and leading practices. *The International Journal of Logistics Management*, 31(2), 209-238.
- Clohessy, T., Acton, T., & Morgan, L. (2017). *The Impact of Cloud-Based Digital Transformation on ICT Service Providers' Strategies*. in 30th Bled eConference: Digital Transformation – From Connecting Things to Transforming Our Lives, 18-21 Jun 2017, Bled, Slovenia, -AIS Electronic Library (ALSeL) Publishers.

- Colicchia, C., Creazza, A., & Menachof, D. A. (2019). Managing cyber and information risks in supply chains: insights from an exploratory analysis. *Supply Chain Management: An International Journal*, 24(2), 215-240.
- Crittenden, A. B., Crittenden, V. L., & Crittenden, W. F. (2019). The digitalization triumvirate: how incumbents survive. *Business Horizons*, 62, (2), 259–266.
- Davis, J., Edgar, T., Graybill, R., Korambath, P., Schott, B., Swink, D., Wang, J., & Wetzel, J. (2015). Smart manufacturing. *Annual Review Chemical and Biomolecular Engineering*, 6, 141-160. doi.org/10.1146/annurev-chembioeng-061114-123255.
- Duerr, S., Holotiuk, F., Wagner, H. T., Beimborn, D., & Weitzel, T. (2018). *What is digital organizational culture? insights from exploratory case studies*. in the 51st Hawaii International Conference on System Sciences; Honolulu, Hawaii, HICSS Publishers. doi: 10.24251/HICSS.2018.640
- Frank, A. G., Mendes, G. H. S., Ayla, N. F., & Ghezzi, A. (2019). Servitization and industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change*, 141, 341–351. doi.org/10.1016/j.techfore.2019.01.014.
- Gangwar, H., Date, H. & Ramaswamy, R. (2015). Understanding determinants of cloud computing adoption using an integrated TAM-TOE model. *Journal of Enterprise Information Management*, 28(1), 107–130.
- Ghezzi, A. & Cavallo, A. (2020). Agile business model innovation in digital entrepreneurship: Lean startup approaches. *Journal of Business Research*, 110, 519–537.
- Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, 29(6), 910-936.
- Giotopoulos, I., Kontolaimou, A., Korra, E. & Tsakanikas, A. (2017). What drives ICT adoption by SMEs? Evidence from a large-scale survey in Greece. *Journal of Business Research*, 81, 60–69.
- Haffke, I., Kalgovas, B., & Benlian, A. (2017). *The transformative role of bimodal IT in an Era of digital business*. in Proceedings of the 50th Hawaii International Conference on System Sciences, at Honolulu Hawaii, HICSS, Publications of Darmstadt Technical University, Institute for Business Studies (BWL).
- Hahn, G. J. (2020). Industry 4.0: a supply chain innovation perspective. *International Journal of Production Research*, 58(5), 1425-1441.
- Hess, T., Matt, C., Benlian, A., & Wiesböck, F. (2016). Options for formulating a digital transformation strategy. *MIS Quarterly Executive*, 15(2), 123–139.
- Hofmann, E., & Osterwalder, F. (2017). Third-party logistics providers in the digital age: towards a new competitive arena?. *Logistics*, 1(9), 1-28.
- Ivanov, D., Dolgui, A., & Sokolov, B. (2018). The impact of digital technology and industry 4.0 on the ripple effect and supply chain risk analytics. *International Journal of Production Research*, 57(3), 829-846.
- Jha, N. K., & Devaya, M. N. (2008). Modelling the risks faced by Indian construction companies assessing international projects. *Construction Management and Economics*, 26(4), 337- 348.
- Kamble, S. S., Gunasekaran, A., & Sharma, R. (2018). Analysis of the driving and dependence power of barriers to adopt industry 4.0 in Indian manufacturing industry. *Computers in Industry*, 101, 107-119. doi.org/10.1016/j.compind.2018.06.004.
- Karltorp, L. (2017). *Digital transformation strategies in small businesses: a case study in the Swedish manufacturing industry*. B.B.A. thesis, International Management Study, JU, Jönköping, Sweden.
- Lee, I., & Lee, K. (2015). The internet of things (IoT): Applications, investments, and challenges for enterprises. *Business Horizons*. 58(4), 431–440.
- Liang, H., Saraf, N., Hu, Q. & Xue, Y. (2007). Assimilation of enterprise systems: The effect of institutional pressures and the mediating role of top management. *MIS Quarterly*, 31(1), 59–87.
- Liboni, L. B., Cezarino, L. O., Jabbour, C. J. C., Oliveira, B. G., & Stefanelli, N. O. (2019). Smart industry and the pathways to HRM 4.0: implications for SCM. *Supply Chain Management: An International Journal*, 24(1), 124-146.
- Loonam, J., Eaves, S., Kumar, V., & Parry, G. (2018). Towards digital transformation: lessons learned from traditional organizations. *Strategic Change*, 27(2), 101-109.
- MacGregor, R. C. (2004). Factors associated with formal networking in regional small business: some findings from a study of Swedish SMEs. *Journal of Small Business and Enterprise Development*, 11(1), 60-74.
- Majumdar, A. & Sinha, S. (2018). Modeling the barriers of green supply chain management in small and medium enterprises: A case of Indian clothing industry. *Management of Environmental Quality An International Journal*, 29(4), 1110-1122.
- Marchet, G., Melacini, M., Perotti, S., Sassi, C., & Tappia, E. (2017). Value creation models in the 3PL industry: what 3PL providers do to cope with shipper requirements. *International Journal of Physical Distribution and Logistics Management*, 47, (6), 472-494.
- Martinsuo, M., & Luomaranta, T. (2018). Adopting additive manufacturing in SMEs: exploring the challenges and solutions. *Journal of Manufacturing Technology Management*, 29(6), 937-957.
- Mathauer, M., & Hofmann, E. (2019). Technology adoption by logistics service providers. *International Journal of Physical Distribution and Logistics Management*, 49 (4), 416-434.
- Moktadir, M. A., Ali, S. M., Kusi-Sarpong, S., & Shaikh, M. A. A. (2018). Assessing challenges for implementing Industry 4.0: implications for process safety and environmental protection. *Process Safety and Environmental Protection*. 117, 730-741. doi.org/10.1016/j.psep.2018.04.020.

- Oliveira, T., Martins, R., Sarker, S. & Thomas, M. A. (2019). Understanding SaaS adoption: The moderating impact of the environment context. *International Journal of Information Management*, 49, 1–12. doi.org/10.1016/j.ijinfomgt.2019.02.009.
- Preindl, R., Nikolopoulos, K., & Litsiou, K. (2020). Transformation strategies for the supply chain: the impact of industry 4.0 and digital transformation. *Supply Chain Forum: An International Journal*, 21, (1), 26-34.
- Samantra, C., Datta, S., Mahapatra, S. S. & Debata, B. R. (2016). Interpretive structural modelling of critical risk factors in software engineering project. *Benchmarking: An International Journal*, 23(1), 2-24.
- Sarvari, P. A., Ustundag, A., Cevikcan, E., Kaya, I., & Cebi, S. (2018). Technology roadmap for industry 4.0, in *Industry 4.0: Managing the Digital Transformation*. Springer International Publishing, Cham, 95–103.
- Singh, R., Baird, A., & Mathiassen, L., (2018). Collaboration risk management in IT-enabled asymmetric partnerships: evidence from telestroke networks. *Information and Organization*, 28(4), 170–191.
- Sony, M., & Naik, S. (2019). Key Ingredients for Evaluating Industry 4.0 Readiness for Organizations: A Literature Review. *Benchmarking: An International Journal*, 27(7), 2213-2232.
- Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0-A Glimpse. *Procedia Manufacturing*, 20, 233-238. doi.org/10.1016/j.promfg.2018.02.034.
- Vendrell-Herrero, F., Bustinza, O.F., Parry, G., & Georgantzis, N. (2016). Servitization, Digitization and Supply Chain Interdependency. *Industrial Marketing Management*, 60, 69–81.
- Vey, K., Fandel-Meyer, T., Zipp, J. S., & Schneider, C. (2017). Learning & development in times of digital transformation: facilitating a culture of change and innovation. *International Journal of Advanced Corporate Learning*, 10(1), 22-32.
- Vial, G. (2019). Understanding digital transformation: a review and a research agenda. *Journal of Strategic Information Systems*, 28(2), 118-144.
- Vogelsang, K., Liere-Netheler, K., Paackmohr, S., & Hoppe, U. (2019). Success factors for fostering a digital transformation in manufacturing companies. *Journal of Enterprise Transformation*, 8(4), 1-22.
- Warfield, J. N. (1974). Developing interconnection matrices in structural modeling. *IEEE Transactions on Systems Man and Cybernetics*, 4(1), 81-87.
- Warner, K. S. R., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. *Long Range Planning*, 52(3), 326–349.
- Woruka, G., Bansbach, Y., Houlder, D., & Jolly, R. (2017). *Digital culture: why strategy and culture should eat breakfast together, in Shaping the Digital Enterprise*. Springer International Publishing, Switzerland.
- Yang, Z. & Lin, Y. (2020). The effects of supply chain collaboration on green innovation performance: An interpretive structural modeling analysis. *Sustainable Production and Consumption*, 23, 1-10. doi.org/10.1016/j.spc.2020.03.010.

## Appendix A

The details and qualifications of the experts

Expert (E)	Experience (years)	Position	Organization	Area of expertise
E1	12	General manager	Logistics service provider company	Logistics management
E2	9	Vice president	Logistics service provider company	Logistics management
E3	6	Chief technology officer	Logistics service provider company	Technology management
E4	8	Associate professor	Engineering department of a research university	Logistics management
E5	5	Assistant professor	Engineering department of a research university	Logistics information management system
E6	6	Manager	Logistics consulting company	Logistics information management system
E7	21	Vice president	Freight logistics association Thailand	Logistics management

