Industrial Digitization, the Use of Real-Time Information, and Operational Agility: Digital and Information Perspectives for Supply Chain Resilience

Article *in* IEEE Transactions on Engineering Management · July 2022

DOI: 10.1109/TEM.2022.3182479

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Industrial Digitization, the use of Real-Time Information, and Operational Agility: Digital and Information Perspectives for Supply Chain Resilience

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***Abstract* — Change is the permanent reality of the digital business world. Firms manage it by their ability and capability to cope with short-term and long-term deviations and disruptions. This paper presents an examination of the supply chain resilience (SCR) of firms operating in the Malaysian Service Sector. The data for this study were collected from 157 managers of 59 firms operating in seven sub-service sectors. Following Organizational Information Processing Theory (OIPT) and reviewing the relevant literature for the conceptualization, we tested a framework that suggests that the use of real-time information (URTI) enhances the SCR. We also found that the industrial digital environment has an important link with the URTI. The results indicate that the URTI is significantly associated with SCR and operational agility, which partially mediates the relationship between the URTI and SCR. We further discuss the theoretical contributions and implications with practical, and policy implications arising from this research.**

***Index Terms*— Supply chain resilience, use of real-time information, operational agility, digital industry environment**

I. Introduction

DISRUPTIONS are a natural phenomenon that has been regularly faced by global firms due to numerous reasons—e.g., competitor maneuvers, natural disasters, and supply shortages, among others. Thus, the ability to cope with disruptions is a common feature of service industry firms. Service offerings cannot be stored in advance as manufacturing products, and other factors—e.g., improvement of performance in terms of lead-times, perishability, timeliness, and non-conformities—are making them more prone to disruption and change [1], [2]. At the intra-organizational level, supply chain resilience (SCR) is the ability and capability of a firm to cope with short-term and long-term change and disruption. Previous studies have suggested that SCR is an outcome that could be integrated with processes and dynamics suited to create the redundancy, flexibility, adaptability, and agility that enable firms to cope with and recover from supply chain disruptions [3]-[6] integrated information processing theory and concluded that the explorative use of information technology (IT) with suppliers and customers has significant effects on SCR.

SCR is the capability of a firm to smoothly recover from disruption. A good SCR shows the bounding of the different components of supply chains before, during, and after disruptions. Information collection and sharing is a crucial process and step in any type of disruption. Business operations enabled by the use of real-time information (URTI) create opportunities for improvement in difficult times [7], [8]. The URTI may lead to the leveraging of digital technology to cope with any unexpected exogenous shocks to building SCR. IT and its related technologies are significantly challenging conventional wisdom in academic thinking and traditional operation management theories [9], [10].

In the era of industry 4.0, future-ready companies are modular and agile; data are strategic assets that are shared and accessible to all those in the company who need them [11]. The capabilities of firms are set by the industrial environment in which they operate. A low-tech industrial environment does not support URTI initiatives. Operational agility is a firm's operational capability to improve business processes by incorporating innovative opportunities to counteract constraints [12]-[14] proposed that a firm's operational agility can be enhanced through the implementation of digital technology.

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On the other hand, previous research has shown that information facilitates business operations [15], [16]. Each source of information provides visibility into its related domains—e.g., corrective actions relating to the flows of raw materials, finished goods, and services as needed [17], [18]. Information also enhances any opportunities to build stronger relationships with stakeholders [19]-[21]. Therefore, we inferred that the URTI enhances operational agility and SCR. Additionally, operational agility can improve SCR.

Past research has shown that the development of adaptive responses [22], digital technology [23], [24], horizontal coopetition [25], information transmission [26], operational adaptation [27], and the adoption of technology [28] are factors that contribute to the process of building a positive impact on SCR. Others have suggested the use of digital technologies to predict any future emergencies and provide solutions [29]-[32]. However, few studies on SCR have hitherto gauged the impact of the URTI and operational agility. SCR is no longer understood in terms of stability, but of adaptation through real-time information and of transformation through agility [33]. Business-related information provides the space needed to make decisions regarding specific situations or environments. Information also helps in addressing uncertainties and disruptions by alleviating the structural mechanisms interlocked with produce and service flows. The literature and studies on real-time information—as part of Information Processing Theory—and its links to operational outcomes are gaining more attention [7]. For instance, the URTI helps to engage customers and mediates the relationships among different business players. Other interlinked arenas that the URTI could facilitate are collaboration, trust, and enhanced digital capabilities [7], [56]. Big data and the knowledge-based view are closely related to information sharing and analytics and can assist in new product success [59]. Similarly, the links between real-time information and manufacturing are also explored [46]. However, the interlocks between industrial digitization, the URTI, operational agility, and SCR are still being studied. Therefore, this study offers novel insights through the lens of Organizational Information Processing Theory (OIPT) to investigate these interlocks.

This study suggests that the use of real-time information is a strategic option whereby firms can deal with disruptions through innovative choices and opportunities. This study contributes to the literature on SCR in the following ways. First, it proposes the URTI adaptation to enhance operational agility and SCR. This adaptation provides room to innovate the processes and routines and expedites the recovery time from disruptions. The second contribution of this study is an explanation of the mechanism occurring between the URTI and SCR through operational agility. It clarifies that, although the benefits of the URTI do tend to enhance SCR, this effect is explained by the mediating influence of operational agility. In this way, this study contributes to OIPT, which suggests that firms need quality information to cope with environmental uncertainty and improve their decision-making [34].

This paper is structured as follows. Section two presents a discussion of the relevant theory and constructs of the study. Section three explains the research design and approach, and section four a depiction of the analysis and results. Section five presents a discussion of the implications, a conclusion, and directions for future research.

II. Literature Review And Hypothesis Development

A. Organizational Information Process Theory

Organizational Information Process Theory depicts that organizations need quality information to address the environmental uncertainty that stems from the complexity and dynamism of the environment. To address such uncertainty, disruption, and increased information needs, organizations develop buffers suited to reduce their effects and implement structural mechanisms and information processing capabilities to enhance the information flow and thereby reduce uncertainty [35]. [35] proposed that organizations can weaken the negative effects of environmental uncertainty and disruption by enhancing their information processing capabilities. Previous studies have reported that, based on information processing theory, the usage of IT enhances the sharing and processing of information, which is beneficial for disruption recovery [30], [36].

The external use of IT refers to the usage of various tools—e.g., enterprise digital Infrastructure (EDI), customer relationship management (CRM), the Internet, or cloud computing—that help to connect supply chain partners and enable the digitalization of a firm's activities beyond its boundaries [37], [38]. These tools help to establish a firm's electronic linkage beyond its boundaries, with its suppliers and customers, which significantly enhances its capability to respond, revamp, and recover from supply chain uncertainties and disruptions. IT acts as a necessary intermediary in sharing information across the firms' boundaries [39], [40]. IT connects the suppliers and customers that enable the information processing ability of the firms, thus empowering them to swiftly cope with any disruptions and uncertainties in cooperation with their supply chain partners [41], [42].

Previous research studies have recognized the importance of OIPT in the supply chain management domain to understand how organizations are using different applications and patterns of IT with their various stakeholders, like suppliers and customers, to build SCR. The industrial digital environment—with technological advancements in the IT domain like cloud computing and the Internet-Of-things (IoTs)—may strongly influence the capability to process and share information with all stakeholders; specifically, the URTI. Further, Industry 4.0 tools enable the URTI, which may enhance a firm's response and accuracy, resulting in improvising operational agility. A firm's operational agility helps in building SCR. This study examined the role played by the industrial digital environment in the URTI and its impact on operational agility and SCR.

B. The Industrial Digital Environment and the Benefits of the Use of Real-Time Information

The 'industrial digital environment' involves technological advancements like the Industry 4.0 tools—e.g., cloud

computing, the IoT, Internet-enabled technologies, and many others—that enable the quick processing of data, and the faster sharing of real-time information with all business units, which may enhance radical innovations and may create significant opportunities for the industry. Technological capability—and, specifically, IT—plays a major role in supply chain collaboration among business partners, enabling the faster sharing and exchange of information, which can minimize supply chain disruptions [43].

The URTI is related to the responses given by customers after the service takes place, preferably through a customer relationship management (CRM) tool [8], [15]. Technological advancements, such as Industry 4.0, and tools like cloud computing enable the sharing of information with various stakeholders—e.g., a firm's employees, suppliers, logistics service providers, and customers. Such information sharing takes place primarily through cloud computing, which provides several computing infrastructures—i.e., software as a service (SaaS). The responses provided by the customers, which are gathered through their interaction with the SaaS application, can be used to enhance their purchase behaviors. Such responses are gathered based on the customers' satisfaction levels, which are reflected in their ratings of products and services. Previous studies have reported several benefits provided by the URTI, such as increasing supply chain performance [44], [45], increasing production [46], improved transportation [47], and creating positive customer behaviors [48]. Thus, the industrial environment—with technological advancements like the Industry 4.0 tools—enables the sharing and receiving of real-time information on new product ideas with customers, employees from different firm departments, suppliers, and other business partners like logistics service providers. Thus, we formulated the following hypothesis.

H1: The industry's digital environment is positively related to the benefits of the use of real-time information.

C. The Benefits of the Use of Real-Time Information and Operational Agility

Operational agility is about providing quick responses, taking effective actions, and achieving cost efficiency in internal and external operational processes. In the supply chain and logistics domains, agility refers to responses to demand, responses of customers, and joint planning [49]. Further, [50] defined operational agility as the "capability of organizations to satisfy demands and several changes by considering four different aspects –speed, accuracy, cost-efficiency, and flexibility at both the internal and external levels".

Various technologies—such as the IoT and cloud computing—help in the URTI drawn from data. Previous studies have indicated several benefits bestowed by the URTI after the service has been provided. The real-time sharing of information helps to capture customer responses of customers and, in turn, to increase supply chain performance [44], [45] and improve production levels [46], [47], resulting in ever more agile operations between the connected business units [51], [52]. Real-time information sharing, which improves the dynamic capabilities of an organization, refers to its capability to promptly respond and adapt to changes and to the data processing that enables it to tackle any market changes [53], [54]. Organizations equipped with electronic devices capture real-time data and information, which are then used daily in supply chain operations. These dynamic capabilities help in improvising operational agility [55]. [56] reported that technological capability is positively related to supply chain agility. Real-time information is shared by companies through digital technologies, whereby crucial and real-time information is shared with and transferred to global international partners, enabling them to respond quickly and become more agile [57].

Previous research studies have revealed that digital technologies such as the IoTs have a huge potential to transform business processes and knowledge management in ways suited to play a significant role in the operational agility of business network partners [58], [59]. This is because digital technologies enable business organizations to integrate, create, and reshape their internal and external operations, thus resulting in their attainment of data analysis-driven leadership in continuously changing business environments and of increased agility [50]. The usage of the IoTs enables operational agility thanks to devices connected to the Internet that can promptly receive, share, and process information [60], [61]. Through sensors and Internet-enabled technologies, companies not only collect, process, and share data, but are also able to respond immediately and in a timely fashion to any changes taking place in the business environment, thus achieving significant improvements in their operational agility [62], [63]. Based on the findings of previous studies, we formulated the following hypothesis.

H2. The benefits of the use of real-time information are positively related to operational agility.

D. The Benefits of the Use of Real-time Information and Supply Chain Resilience

The development of a robust supply chain network suited to support the sharing of the right information among supply chain partners is important in a dynamic environment and can significantly reduce the risk [64]. [56] reported that any increases in information sharing decrease supply chain uncertainty. The academic literature on supply chain management has provided theoretical aspects, but it has hitherto failed to provide any research support for the operationalization of the concept of SCR [26]. Such a concept is in its nascent stages; as such, limited definitions of it are available in the existing literature [57]. Therefore, the resilience concept requires further empirical investigation [65]. The extant literature, which has focused on empirical research related to the SCR concept, lacks definite and crucial practitioner-related insights [66]. Thus, this study was aimed at significantly addressing this research gap by examining the complex interrelationships between the industrial digital environment, the URTI, operational agility, and SCR in the context of the Malaysian service sector environment.

[67] defined SCR as the "capability of a supply chain to

revert to its normal operating performance". This return to normal should take place within an acceptable period after a disturbance [68]. The authors reported that SCR is significantly influenced by supply chain connectivity and by the receiving and sharing of information. Supply chain connectivity refers to the technology-based infrastructure through which information is shared with supply chain partners [69] and IS refers to the speed, quality, and nature of the information thus shared [70]. [71] defined SCR as the "adaptive capability of the supply chain to prepare for unexpected events, response to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function." However, [67] argued that resilience is an output that depends on certain capabilities—e.g., supply chain visibility, which is based on two crucial resources: supply chain connectivity and information sharing. Previous studies have indicated that the receiving and sharing of real-time information help to capture customer responses and, in turn, improves supply chain performance [44], [45] and production [46], [47]. As the sharing of real-time information has been linked to supply chain performance, there may be a strong association between the URTI and SCR.

We considered the SCR concept along the same lines as [67]—i.e., as being dependent on supply chain connectivity and information sharing. Technological advancements like Industry 4.0 and tools like cloud computing enable the sharing of real-time information with supply chain partners, including customers, and thus enhance supply chain connectivity (the technology-based infrastructure through which information is shared with supply chain partners) and IS (the speed, quality, and nature of the information thus shared) which are the antecedents of SCR. The prompt and faster sharing of real-time information through a technology-based infrastructure enables a supply chain to revert to its normal operating performance within an acceptable period after a disturbance; thus, the URTI can significantly influence SCR. We, therefore, formulated the following hypothesis.

H3: The benefits of the use of real-time information are positively related to supply chain resilience.

E. Operational Agility and Supply Chain Resilience

The extant literature has found various antecedents of SCR—e.g., agile characteristics, collaborative relationships, and supply chain re-engineering [68]. Previous studies have reported that supply chain agility is positively associated with SCR [72], [73]. Agility is considered one of the key antecedents of SCR [74]-[77]. Sullivan-Taylor and Branicki [78] found that agility is the most important capability for enhancing resilience. [79] reported that agility is one of the most important drivers of SCR. The capability of speeding up operational processes is traditionally related to agility [80], which is an important driver of the development of resilient supply chains [81].

[68] identified four capabilities for the development of SCR—supply chain (re-engineering), agility, collaboration, and risk-awareness—and operational agility as one of the SCR principles that have to be taken into account in supply chain design. [82] proposed four principles of supply chains and [68] proposed four pillars of SCR. [68] and [83] identified visibility, flexibility, and velocity as antecedents of agility required for the development of a resilient supply chain. SCR can be achieved by developing capable networks capable of rapidly responding to dynamic conditions [68]. Thus, operational agility can act as an important antecedent in achieving SCR; for instance, inventory-related risks can be reduced with a responsive supplier [84]. Based on the findings of the previous research studies, we formulated the following hypothesis.

H4: Operational agility is positively related to supply chain resilience.

F. The Mediating Effect of Operational Agility

In sub-sections C, D, and E, strong theoretical arguments are provided to hypothesize the relationships between the URTI and operational agility, the URTI and SCR, and operational agility and SCR. These hypothesized relationships raise the possibility of operational agility playing a mediating role between the URTI and SCR. The URTI enables the timely sharing and transferring of crucial information among all connected business units, resulting in an improvement of a firm's capabilities to promptly respond to changes and in the processing of the data that enables tackling market changes, thus bringing more agility. The URTI strongly influences SCR based on two concepts—supply chain connectivity and information sharing—that are the antecedents of SCR. Supply chain connectivity is related to a technology-based infrastructure through which information is shared with supply chain partners, while information sharing refers to the freshness, quality, and nature of the information that is shared. Technological infrastructures like cloud computing and the IoT scan processes enable the prompt and swift sharing and transfer of information with all business units, enabling the supply chain of a firm to revert to its normal operation within an acceptable time frame following a disturbance, thus influencing SCR. The operational agility of a firm strongly influences SCR (as discussed in sub-section 1.5, wherein strong arguments are provided to support a positive relationship between operational agility and SCR).

Agility is the ability to quickly respond to any unpredictable changes. Operational agility reflects the ability of business processes to exploit opportunities for innovation and competitive action [85]. From this study's perspective, operational agility supports the enhancement of SCR in relation to the URTI. According to [86], operational agility alters organizational structures, processes, systems, and culture to align them with any changing strategic priorities. Previous studies have found that agility plays a mediating role between different constructs. [87] found that agility mediates the relationship between firm innovativeness and SCR. [88] proposed that supply chain agility mediates the relationship between supply chain ambidexterity and SCR. Based on these arguments, we formulated the mediating hypothesis and developed the conceptual framework presented in Fig. 1. The table in the Appendix highlights the discussed studies and their

interlinks to explore the knowledge gap that interlocks with our underlying constructs.

H5: Operational agility mediates the relationship between the benefits of the use of real-time information and supply chain resilience.

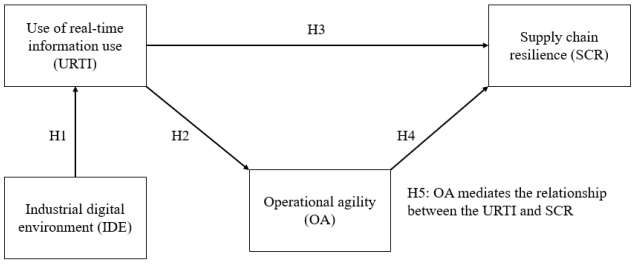

Fig. 1. Proposed conceptual framework

III. METHODOLOGY

A. Procedures and Sample

The prime focus of this study was to gauge the effectiveness of the industrial digital environment, the URTI, operational agility, and SCR. To do so, we collected data from 157 managerial level individuals employed in 59 firms belonging to Malaysia's service sector, which is just as prone to supply chain disruptions as the manufacturing one. The firms were therefore the units of analysis, and individual research participants were the units of observation. The respondents, who held strategic positions in their firms, were knowledgeable about strategic adaptation through real-time information and about transformation through agility to enhance SCR. Their relevant knowledge, both in theory and in practice, therefore made them the appropriate choice for data collection.

As all our sample firms' workforces counted more than 250 employees, they could be classified as large-sized. The fourth-quarter report of 2020 by the Department of Statistics Malaysia shows that the service sector accounted for a 57.8% contribution to the country's economic activities [89]. The data were collected from four provinces of Malaysia—i.e., Johar, Pahang, Perak, and Selangor. We administered an online survey over six months in 2020-21, collecting 201 responses, 157 of which were found to be usable. Based on their expressed consent and preferences, the respondents were sent a link to the survey questionnaire after being contacted via email, WhatsApp, SMS, and phone calls. A cover letter was attached, stating the details; the purpose of the study, assuring the confidentiality of the responses, the anonymity of the respondents, and the ethical approval. Table 1 shows the demographics of our respondents.

TABLE I
DEMOGRAPHICS

Category	Type	Frequency	%
Gender	Male	112	71.34
	Female	45	28.66
Designation	CEO	8	5.10
	COO	18	11.46
	Director	71	45.22
	Head of departments	60	38.22
Sub Service Sector	Bank	8	13.36
	Delivery service	8	13.36
	Education	12	20.34
	Mobile Communication	6	10.17
	Recreational services	9	15.25
	Retail services	11	18.64
	Travel & tourism	5	8.47

N = Managers (157), Firms (59)

B. Measures

All constructs were adapted from reliable sources. The questionnaire's content validity in the context of Malaysia was analyzed with the help of an expert panel involving academics and practitioners. We received a few minor recommendations from experts—e.g., that item #2 of the industry digital environment construct should be item #1 in the questionnaire. All our consulted experts' suggestions were incorporated into the questionnaire, which was then finalized for data collection. The questionnaire contained items eliciting personal information from the respondents—such as their titles, education, age, and experience, with a few firm characteristics. It also comprised 18 items measuring the four constructs.

All the items of the constructs were gauged on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The respondents were instructed to circle one of the points from 1-5. The industrial digital environment, which was adapted from [90], and the URTI [8] utilized three items each. Operational agility was quantified with eight items adapted from [50], one of which was later deleted due to its low quality. The SCR concept was quantified with four items taken from [67].

C. Data Quality Assurance

The previous literature suggests performing a quality check of the data by testing them for common method variance to avoid variation in responses [15], [91]. To do so, we took a marker variable approach. We incorporated 'employee loyalty as a marker variable with the study constructs in a correlational investigation [92], [93]. The effects of the inclusion of the marker variable were small (MV → industry digital environment = 0.002), (MV → operational agility = 0.009), (MV → SCR = 0.011), and (MV → URTI = 0.08); thus establishing low common methods bias.

We took a different approach to confirm the quality check of data by testing for non-response bias by using and comparing the responses of the first 20 and the last 20 participants on all variables [93], [94]. The results were found to show no significant differences between the two subsets of respondents. Therefore, non-response bias in the dataset was deemed not to be a concern.

IV. Data Analysis

We took a partial least squares structural equation modeling (PLS-SEM) approach to evaluate the estimated parameters in a multivariate model, which reflects the hypothesized relationships between observable and latent variables [95]. Two techniques for SEM are generally accessible: covariance- and variance-based. For this study, we took a variance-based approach due to it not being constrained by a normal data distribution and being able to handle a complicated model, including a mediation test [96], [97]. All scales were assessed reflectively, and the model was tested using the SmartPLS 3 software [95], [97].

A. Measurement Model

The assessment of the measurement model was conducted in two stages: reliability and validity [96].

To assess reliability, we utilized factor loading, composite reliability (CR), and Cronbach's alpha (α), as proposed by [98]. After eliminating one item with low loading—OA1 "The reliability of our offerings has increased"—the results from the remaining ones were found to exceed the commonly used threshold requirements for the three measures. Specifically, the factor loadings of all items were found to range between 0.703 and 0.895, Cronbach's alpha (α) was found to range between 0.703 and 0.848, and composite reliability was found to range between 0.732 and 0.885, all statistics are presented in Table II. We then proceeded to examine two forms of validity: convergent and discriminant. The average variance extracted (AVE) was used to assess convergent validity. As seen in Table II, the obtained AVE values were found to range from 0.758 to 0.809, thus falling above the required threshold of 0.5 and indicating satisfactory convergent validity. Discriminant validity was evaluated based on the heterotrait-monotrait ratio of correlations (HTMT) approach, as presented in Table III. The HTML ratio of all constructs was found to fall below the 0.85 cut-off value and the correlation between each pair of constructs was found to be lower than the square root of the AVE for each construct, thus indicating discriminant validity.

TABLE II
RELIABILITY AND CONVERGENT VALIDITY

Constructs	Brief descriptions of measurement items	Code	Loading	α	CR	AVE
Industry digital environment	The technology in our industry is changing rapidly.	IDE1	0.801	0.761	0.773	0.761
	Technological changes provide big opportunities for us in our industry.	IDE2	0.736			
	Many new digital product ideas have been made possible by technological breakthroughs for us in our industry.	IDE3	0.758			
Real-time information use	For us, adopting real-time information receiving and sharing applications has many advantages.	URTI1	0.848	0.703	0.732	0.809
	Real-time information receiving and sharing applications are useful instruments for our increasing operational excellence.	URTI2	0.822			
	Overall, we consider the adoption of real-time information receiving and sharing to be a useful strategic option.	URTI3	0.775			
Operational agility	Our day-to-day operations are flexible, to deal with customized demand.	OA2	0.751	0.848	0.883	0.788
	Our offerings are more cost-efficient than those of our competitors.	OA3	0.776			
	We are very quick in delivering our offerings.	OA4	0.789			
	Our responses to market changes are very reliable.	OA5	0.743			
	We are very flexible in our offerings to adapt to market changes.	OA6	0.712			
	We promptly redesign our offerings to adapt to market changes.	OA7	0.703			
	We are very quick in exploiting market opportunities.	OA8	0.774			
Supply chain resilience	Our supply chain flows are quickly restored.	SC1	0.824	0.825	0.885	0.758
	We do not take long to recover our supply chain performance.	SC2	0.895			
	Our supply chain easily recovers to its original state.	SC3	0.782			

	Our supply chain disruptions are dealt with quickly responses.	SC4	0.735			

TABLE III
DISCRIMINANT VALIDITY

Construct	URTI	IDE	OA	SCR
URTI	-	-	-	-
IDE	0.625	-	-	-
OA	0.519	0.654	-	-
SCR	0.688	0.566	0.745	-

Note: URTI = Use of real-time information; IDE = Industry digital environment; OA = Operational agility; SCR = Supply chain resilience

B. Structural Model

To test the basic model and hypotheses, we performed PLS-SEM using 5,000 bootstrapping sub-samples. The model was measured by the coefficient of the determinant (R2), predictive accuracy (Q2), standardized root mean square residual (SRMR), and Normed Fit Index (NFI). The R2 values of endogenous variables were found to be satisfactory, indicating sufficient explanatory power of the model, Q2 greater than 0 depicted predictive accuracy, a SRMR value lower than 0.08 and an NFI value greater than 0.90 explained a good model fit [99]-[101], as shown in Table IV.

TABLE IV
MODEL GOODNESS OF FIT

Construct	R^2	Q^2	SRMR	NFI
URTI	0.258	0.044	0.071	0.913
OA	0.412	0.192		
SCR	0.516	0.320		

Note: URTI = Use of real-time information; OA = Operational agility; SCR = Supply chain resilience

Next, we analyzed the structural model by assessing the path coefficient (β) and t-value for each relationship, Fig. 2 presents the structural modeling analysis. As recommended by [99], path coefficient values greater than 0.1 with t-values greater than 1.96 are considered significant at the 5% level. The results revealed that the industry digital environment significantly influences the use of real-time information (β = 0.398, t = 4.033, p = 0.000), thus supporting H1. The results also confirmed that the benefits of the sharing and use of real-time information positively affect operational agility (β = 0.460, t = 5.404, p = 0.000) and supply chain resilience (β = 0.191, t = 2.007, p = 0.022), therefore supporting H2 and H3. Regarding the influence of operational agility on supply chain resilience, the results showed that operational agility has a significant impact on supply chain resilience (β = 0.534, t = 6.038, p = 0.000), which supports H4 (see Table V).

TABLE V
PATH ANALYSIS

Hypothesis	Effect	B	S.E	t-value	p-value	Result
H1	IDE → URTI	0.398	0.099	4.033	0.0	Supported
H2	URTI → OA	0.460	0.085	5.404	0.0	Supported
H3	URTI → SCR	0.191	0.095	2.007	0.02	Supported
H4	OA → SCR	0.534	0.088	6.038	0.0	Supported

Note: URTI = Use of real-time information; IDE = Industry digital environment; OA = Operational agility; SCR = Supply chain resilience

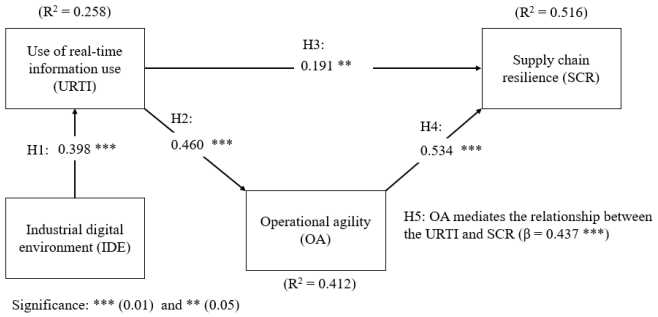

Fig.2. Hypothesis results

C. Mediation Analysis

In this study, we also investigated the mediating effect of operational agility between the benefits of the URTI and SCR in the path model. We, therefore, examined the indirect effect of the URTI on SCR through operational agility. Table VI (a) and (b) provide the results for the direct effect of the URTI on SCR and for its indirect effect through operational agility.

The results reveal the mediation effect of operational agility, with both direct and indirect effects being found to be significant. Subsequently, the variance account for (VAF) was used to examine the degree of mediation. The VAF computes the magnitude of the indirect effect in relation to the total effect [98]. The results revealed that operational agility partially mediates the relationship between the URTI and SCR, as the resulting VAF value was found to be 56.3%, therefore partially supporting H5.

TABLE VI (a)
MEDIATION EFFECT

Hypothesis	Total Effect	β	t-value	p-value
H5	URTI → SCR	0.437	5.114	0.000

TABLE VI (b)
MEDIATION EFFECT

Indirect Effect	B	t-value	p-value	VAF	Result
URTI → OA → SCR	0.246	3.964	0.000	56.3%	Partially Supported

Note: URTI = Use of real-time information; OA = Operational agility; SCR = Supply chain resilience

V. Discussion, Implications, And Conclusion

A. Major Findings

In this study, we examined the impact of the URTI on SCR as well as the mediation role played by operational agility. To do so, we focused on the major sub-sectors of the Malaysian service industry. [102] suggested that any shortages of materials and components attributed to politics, natural disasters (e.g., earthquakes), or pandemics are the only factors impacting resilience. [24] emphasized a focus on the factors that enhance supply chain resilience. Such identification and testing of the antecedents of SCR provides new insights and knowledge from the service industry perspective. The industrial digital environment sets the technological adoption momentum—i.e., the URTI. [103] posited that a country's technological environment, which defines the competition between local and global firms, sometimes produces an impenetrable line between such competitors.

Real-time information technology can provide service providers with up-to-date information on the attributes and quality they offer. [104] shared that the increase in the speed with which information is delivered to decision-makers is directly linked to the speed with which decisions are made. Prompt and speedy information is helpful to quickly respond to changes in the environment and to understand the consequences of any such responses. The rapid delivery of information is significant in dealing with both short- and long-term interruptions and disruptions in business operations and performance. In case of any uncertainty and disorder, real-time information can provide the current position of the offering, firm, or market. Therefore, it provides a cushion suited to adjust the operation(s) and method(s) according to the needs of the situation. IT has generally been considered an enabler of operational agility [105]; on the other hand, [106] insisted that the impact of IT is limited unless it is aligned with the business processes of a firm. In this regard, this study sheds light on the role played by operational agility in affecting the connection between the URTI and SCR. [107] posited that operational agility is the aptitude of a firm's internal business processes to rapidly cope with market or demand changes. A firm's operational ability to improve and initiate innovative business processes after receiving/sharing real-time information enhances a supply chain's ability to weather any short- or long-term changes and disruptions.

Operational agility also incorporates the opportunities available to counter any constraints faced by a firm. Information and operational agility can provide solutions to unexpected situations. In a nutshell, this study proposes that firms require real-time information to improve SCR, and that operational agility partially mediates this relationship.

B. Contributions

This study contributes to the existing literature in the following ways. First, it provides evidence that the URTI enhances operational agility and SCR. The past literature suggests that the URTI supports the development of other capabilities—e.g., analytical capability [108], customer engagement [15], decision-making capabilities [109], environmental management [110], process capability [111], and sales [8], [15]. Second, this study demonstrates the mediation role played by operational agility between the URTI and SCR, which had not been investigated by the extant literature. It shows how a capability helps to create/enhance another one in the presence of the related IT technology. By ensuring the availability and use of real-time information, such technology decreases the response times involved in dealing with undesirable situations. Third, this study took OIPT as the theoretical lens through which to examine the proposed relationships between the industrial digital environment, the URTI, operational agility, and SCR, which had not hitherto been explored. By doing so, it uniquely extended the theoretical application of OIPT and established the significance of the URTI and the role it plays in influencing operational agility and SCR. Fourth, this study suggests that real-time information is pivotal and necessary to cope with any environmental and market uncertainty and improve firm decision-making. This is consistent with the roots of OIPT. In an information-rich environment, those firms that enact practices and structures that support efficient information processing achieve better market success than those with lower levels of 'information age' firm characteristics [113].

C. Practical and Policy Implications

This study provides managers and policymakers with several implications useful to address SCR challenges. Firms in the service industry are facing fierce local and global competition due to fast-changing technology and more exigent customers. This pressure urges supply chain practitioners and policymakers to provide micro and macro environments suited to improve SCR. Our findings suggest that policymakers should focus on the technological environment and adaptation to sustain the service sector supply chain. Thus, a greater use of technology will help to increase the capabilities of firms. Real-time connectivity with stakeholders provides a cushion and an opportunity for firms to make fast and effective decisions.

Based on empirical results, this study's findings further suggest that governments should run awareness campaigns and seminars for top managers and policymakers to adapt to the newly available technology to enhance capabilities. Should such players be convinced to adopt the technology suited to support and enhance operational agility and SCR, they may find that the benefits outweigh the cost and effort required. A more intensive use of technology provides an opportunity for improved SCR, particularly against unforeseen circumstances such as the COVID-19 pandemic. Additionally, to improve the current technological infrastructure and to ease the adoption of the use of real-time information technology in operations, governments and policymakers should offer tax rebates and subsidies as per the needs of the service industry. Such an initiative, which may be more feasible for competitive service firms or struggling service firms, could provide a boost to market competition and the economy. By contrast, such initiatives could be a problem for a few firms; for example, small-medium enterprises, which could struggle in a

technology orientation and capability building contest. Therefore, to overcome this dilemma, policymakers should consider the realities of small-medium enterprises while defining any technology-adoption policies aimed at building capabilities. Often, as suppliers or wholesalers, small firms provide services to large ones and, should the latter implement 'costly' real-time information systems to support supply chain resilience, small firms could struggle to cope with the related requirements.

Our findings validate operational agility as a critical capability for SCR. Firms wishing to improve their SCR need to constantly assess their operational agility factors—e.g., flexibility in day-to-day operations and response times to market changes. Additionally, our findings also suggest the adoption of proactive and reactive approaches while integrating real-time information technology with operational agility to combat supply chain vulnerability.

D. Limitations and Directions for Future Research

The sample used for this study consisted of firms from the service sector; thus, future research could select manufacturing sector firms to examine this study's model. Furthermore, to generalize the impact of the URTI on SCR, future studies could choose different sources of real-time information to check their impact on operational agility and SCR. Future studies could extend this study's model to include other theoretical lenses. In particular, we would suggest the integration of complex adaptive system theory. Similarly, future studies could also extend this study's model by including a different mediator. Specifically, we would suggest a few novel constructs—i.e., supply chain innovation, supply chain ambidexterity, and management capabilities. Finally, to understand the handling and management differences between short- and long-term changes and disruptions, future studies could adopt a longitudinal method to more deeply understand SCR.

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APPENDIX
STUDIES, THEORIES, CONSTRUCTS, FINDINGS, AND KNOWLEDGE GAP

Study	Theories or main concepts	Constructs or topics	Key findings	Knowledge gaps

[7]	Information processing	Real-Time Information Receiving, Customer Orientation, Gender, Customer, Engagement	Real-time information receiving is the antecedent of customer engagement, and customer orientation mediates that relationship as well.	Real-time information usage in the service industry would add value to downstream operations.
[44]	Resource-Base View Relational, View, Swift and Even Flows	E-Business Capabilities, Production Information Integration, Operational Performance	E-Business technologies and supplier integration lead to better performance.	Real-time information usage has a relationship with SCR capability.
[46]	Real-Time Manufacturing Information Integration Service	Internet of Manufacturing Things	Real-time Manufacturing Information Integration Service (RTMIIS) has been designed to achieve seamless dual-way connectivity and interoperability.	Real-time information usage could have a relationship with operational agility.
[52]	Inductive Theory	Information Requirements Characteristics, IoT Technology Characteristics, Information Requirements-IoT Technology Fit, Strategic Value	The modified task-technology fit approach is used to investigate how the IoT technology can be incorporated into the three rhythms (mobilization rhythm, preliminary situation assessment rhythm, and intervention rhythm) and enhances emergency response operations.	Real-time information usage has a relationship with SCR capability through operational agility.
[56]	Information Processing, High-Reliability Social Exchange	Supply chain, Agility, Collaboration, Sustainability, Information Sharing, among others	Organizations can enhance their resilience potential by modifying their strategic assets.	Operational agility could have a relationship with supply chain resilience.
[57]	Systems Theory, Resource-Based View	Supply Resiliency Enhancers, Supply Resiliency Reducers	Resiliency enhancers are created by combining both tangible (i.e., physical capital resources) and intangible resources (i.e., human capital) and organizational and inter-organizational capital resources.	Real-time information usage has a relationship with SCR capability through operational agility.
[59]	Complexity, Knowledge-Based View	Traditional Marketing Analytics, Big Data Analytics, Knowledge Fusion, New Product Success	Knowledge fusion to improve new product success is not automatic and requires strategic choices to obtain its benefits.	Innovation in processes and routines expedites the recovery time from disruptions.
[64]	Graph Theory	Traditional Supply Chain, Lean Supply Chain, Agile Supply Chain	Organizations select suitable supply chain strategies based on customer sensitivity and risk alleviation competencies and the transition required in tune with the market requirements in which they operate.	Operational agility has a relationship with SCR.
[65]	-	Behavior and Dynamics, Capabilities, Strategy, Performance	Provided supportive literature to understand the interfaces between organizational and infrastructural resilience.	Real-time information usage has a relationship with SCR capability through operational agility.