Empirical Investigation to Assess the Impact of ICT Deployment in SCM Using SEM

Prashant R. Nair, Amrita School of Engineering, Coimbatore, India
Anbuudayasankar S. P., Amrita School of Engineering, Coimbatore, India
Sriram R. Devanathan, Amrita School of Engineering, Coimbatore, India
Raghuram R. P., Amrita School of Engineering, Coimbatore, India

ABSTRACT

The adoption of information and communication technology (ICT) is becoming increasingly ubiquitous, and it is prominent in supply chain too. The objective of this paper is to perform an empirical investigation to assess the impact of ICT in supply chain management (SCM) using structural equation modeling (SEM). A survey questionnaire was administered and collected from 200+ SCM professionals in sectors such as manufacturing, services, MSMEs, international companies, as well as SCM/ERP professionals working as domain experts in IT and service companies. Confirmatory factor analysis was used to validate the suggested empirical model and hypothesis based on the impact of ICT deployment on SCOR Level I metrics/indicators as constructs. This research appends to the literature on supply chain performance measures and addresses a recognized gap in terms of rubrics, constructs, assessment frameworks, and metrics of these ICT benefits and capabilities in SCM. This framework can be used by any enterprise irrespective of the geography or country, vertical or domain, manufacturing or services.

KEYWORDS

Empirical Investigation, Information and Communication Technology, Structural Equation Modeling, Supply Chain Management

1. INTRODUCTION

Fast technology developments and vibrant market dynamics have altered the enterprise landscape as also fundamentally transformed prevailing business models. Information and Communication Technology (ICT) applications and deployment has unlocked the gates for enterprises to compete in any marketplace. Enterprises of all hues and sizes are exposed to the present-day challenges of bigger competition, pricing pressures and globalization.

ICT tools are excellent enablers of business processes. ICT tools and applications in various supply chain processes have delivered a competitive edge for all enterprises. This is in terms of effective
access to timely and actionable information as also communication, collaboration and dialogue with various stakeholders. Supply chains have been rendered more transparent, visible, resilient, adaptable and pro-active in decision-making as a result of ICT deployment. And this benefit has percolated to their partners and suppliers, who are connected to the enterprise through an extranet. An inclusive attempt to outline the wide impact of ICT in Supply Chain Management (SCM) is in the definition of functional roles of ICT (Van Hoek et al. 2005) as transaction implementation, partnership and decision support.

The impact of ICT application in SCM is described as enabling information obtainability and visibility; proactive decision-making and enabling communication & co-operation with various stakeholders (Dong et al, 2009). The literature also points out other benefits like improvements in workflow, savings, operational efficiency, customer-interface, innovation & differentiation of products or services (de Barros et al, 2015). There have been investigations on the impact of ICT on SCM from a resource-based view. One granular approach is to divide ICT-based resources into ICT advancement and ICT alignment. ICT advancement is the usage of cutting-edge tools and technologies while ICT alignment reflects the integration of the enterprise with its suppliers and partners enabled through these ICT tools (Wu, 2006). A recent study highlights the role of digital transformation in a co-creation strategy to develop products wherein the customer is in the loop in every step of the product development process (Mihardjo et al, 2020).

The magnitude of annual global supply chain losses is huge. Cargo theft has resulted in loss of $23 billion dollars as per BSI in 2015. 3 out 4 companies have seen disruptions in their supply chains in 2015. Supply chain disruptions resulted in closure of almost 65% of 900 Kentucky Fried Chicken restaurants in Great Britain (Ferrantino and Koten, 2019). Considering the fact that annual global supply chain losses run into billions of dollars, use of ICT tools may not be able to predict natural disasters or terrorist attacks, but can definitely reduce cargo theft, transportation delays, losses and several other disruptions in the supply chain. The ICT advantage for SCM holds immense potential and savings for industry, be it large enterprises or Micro, Small and Medium Enterprises (MSME). This becomes all the more relevant considering the fact that annual global supply chain losses run into billions of dollars. Interestingly trending things in SCM such as VMI, POS, circular supply chain and collaborative replenishment are inherently linked to ICT deployment.

2. LITERATURE REVIEW

ICT impacts all 4Rs of the supply chain namely responsiveness, reliability, resilience and relationships (Christopher, 2016). ICT deployment significantly improves supply chain process integration, which leads to better enterprise performance (Prajogo & Olhager, 2012). ICT deployment for SCM results in a shift from the linkage between physical processes such as inventory, warehouse or shipping to information-based processes across supply chain operations (Gunasekharan & Ngai, 2004). Improving buyer-supplier relationships and accessing actionable knowledge in a suitable manner as also managing dialogue and coordination among various stakeholders are also visible benefits (Kumar et al, 2020). ICT tools such as Blockchain, online platforms and e-commerce also strongly facilitates Green Supply Chain Management (GSCM) & Sustainable Supply Chain Management (SSCM) practices and circular economy, which significantly improve firms’ competitiveness, economic, and environmental performance, which finally translates into organizational performance (Khan and Yu, 2021; Khan et al, 2021[1]; Xue et al, 2021). Likewise, tools such as Internet of Things (IoT) and Big Data Analytics (BDA) are benefitting production environments in terms of dependability and quality and rendering logistics operations more flexible and faster (Koot et al, 2021).

While most researchers and industry practitioners are unanimous in stating that ICT positively impacts the capabilities and the performance of the supply chain with many frameworks having been proposed, there is an identified gap in terms of rubrics, constructs, assessment framework and metrics of these ICT benefits and capabilities in SCM as also in terms of the processes or sectors and
domains that they impact (Nair & Anbuudayasankar, 2016). Evaluating supply chain performance is a complicated activity mainly because this is a transversal process, involving various stakeholders, which contributes to various barriers such as decentralizing historical data, a lack of cohesion between metrics and poor communication between stakeholders (Lima-Junior & Carpinetti, 2017). Various challenges with respect to this measurement are intangibility of some of these measures in the knowledge economy; the dynamic nature of supply chains, subjective evaluation by multiple decision makers and multiplicity of measures (Gunasekaran et al, 2017; Lima-Junior & Carpinetti, 2017).

It is not clear to what extent ICT has contributed to competitive advantage within logistics and supply chains (Gunasekaran et al, 2017). There is also a lack of awareness on performance measures of SCM (Katiyar et al, 2017). Another study specifically focusing on impact of Internet of Things (IoT) on SCM points out that there is an ever-increasing trend in terms of IoT applications in SCM, but we are yet to get a holistic and coherent picture of its impact on SCM performance or be in a position to measure the same (Birkel & Hartmann, 2019). A study has also clearly pointed out that existing supply chain performance models are not able to cope with the potential of intensive supply chain digitization and establish a relationship between decisions and decision criteria (Khan et al, 2019).

The literature points out several challenges with regard to the very concept of supply chain metrics. One interesting observation is that supply chain performance measures exist at strategic, tactical and operational levels and need to encompass financial and non-financial measures (Gunasekaran et al, 2004). Challenges to measure them would be the intangibility of some of these measures in the knowledge economy (Gunasekaran & Kobu, 2007) and the dynamic nature of supply chains (Hassini et al, 2012).

It is also observed that the Supply Chain Operations Reference (SCOR) Process Reference model version 11 by APICS (APICS, 2015) considers the enterprise eco-system in terms of the extended enterprise with suppliers and partners and the addition of ‘enable’ processes primarily meant to address the collaboration and communication between stakeholders in the enterprise, which happen through ICT alignment. Another study specifically focusing on application of Internet of Things (IoT) on SCM points out that there is an ever-increasing trend in terms of IoT applications in SCM, but we are yet to get a holistic and coherent picture of its impact on SCM performance or be in a position to measure the same (Birkel & Hartmann, 2019). A recent comprehensive examination of literature on the application of ICT for SCM also points out to the lack of clarity on the extent of impact of ICT (Gunasekaran et al, 2017). This is further reinforced by the observation that we do not see ICT deployment listed as a metric though it impacts all of the performance measures in various process reference models of SCM like SCOR, GSCF, balanced scorecard and benchmarking. All of the SCOR processes and attributes are influenced by ICT, but this model also does not list ICT enablement as a metric of supply chain performance. One notable exception is the OPQR framework which lists ICT as a Key Process Area (KPA) (Sardana, 2009). Clear and concise rubrics & metrics of ICT deployment for SCM seem to have been less addressed in the literature dealing with the benefits of ICT for SCM.

3. NOVELTY AND RELEVANCE OF THE RESEARCH

The motivation of this investigation is to add to the existing body of knowledge for addressing this gap in the metrics of ICT impact, effectiveness and benefits in SCM as also providing enterprises with a universal benchmark in form of an assessment framework on their ICT deployment in SCM and its dovetailing into SCOR model of the APICS professional body. This structure includes an empirical model which can be extrapolated to an ICT capability index for SCM. The proposed ICT capability index is derived from rubrics and performance indicators of various supply chain performance constructs impacted by ICT. This framework can potentially be used by any enterprise irrespective of the geography or country, vertical or domain, manufacturing or services.

It is evident that there is asymmetry and unevenness in ICT adoption for SCM across various sectors and companies (Nair & Anbuudayasankar, 2016). Measurement of this ICT impact on SCM
aids decision-making and policy makers as it also helps to identify targets, and to track and benchmark progress. Companies can use this empirical model and index to assess to what extent digital matters to them and how it might transform their business models and supply chains as also affect financial performance and diagnostics. This will help them to adapt their organizations, leverage ICT, digitize their operations, and promote open innovation. The research can also open new vistas on selection of appropriate ICT tools after measurement of its impact on the supply chain paradigm and understanding success factors and operational challenges for adoption of various ICT tools (Nair & Anbuudayasankar, 2016). This research work assumes greater significance as a result of the present situation due to Covid-19 pandemic, which has accelerated the need for Industry 4.0, digitalization and embracing of ICT not only for supply chain but also all aspects of the enterprise.

The literature points out several potential supply chain performance enablers and constructs such as supply chain visibility, integration (both structural & functional) cumulative operating cost, communication performance, collaboration performance, operational efficiency, flexibility, responsiveness (Raghuram & Saleeshya, 2016) and customer satisfaction. These investigations use well-defined metrics from the SCOR process reference model and thereby provide a robust research methodology. SCOR performance constructs have been effectively used for gauging the effectiveness of the supply chains (Hasibuan et al., 2018). SCOR has its own set of generic supply chain performance constructs namely reliability, agility & responsiveness, which are considered customer-driven and assets & cost, which are inherently process-driven. ICT deployment is our independent variable. We consider the entire gamut of tools or technologies from EDI to ERP to the latest cutting-edge tools such as IoT or Industry 4.0 as ICT in this investigation. Of course, there may be different granular approaches to ICT, which we have used in a generic manner and these will be explored in the extension to this research.

SCOR model has universal appeal and wide acceptance and is the de facto benchmark for process enhancement for SCM (Ferrantino & Koten, 2019). APICS member organizations & channel partners and its 45,000 members use these metrics for supply chain performance measurement. This standard divides processes into six process management categories such as planning, sourcing etc with benchmarks for operational performance for all of these processes and their sub-processes. SCOR contains over a thousand metrics & good practices for over 200 process elements (de Barros et al, 2015).

4. RESEARCH METHODOLOGY

To address this research problem, which is exploratory in nature, an assorted research method consisting of both descriptive and numerical means seemed appropriate considering the scope and nature of the research problem with the following hypothesis based on SCOR constructs:

H1: ICT deployment improves agility in the supply chain.
H2: ICT deployment improves reliability in the supply chain.
H3: ICT deployment improves responsiveness in the supply chain.
H4: ICT deployment improves asset management efficiency in the supply chain.
H5: ICT deployment reduces operating cost in the supply chain.

The detailed survey questionnaire combines quantitative and qualitative inputs with adequate provision for open-ended questions with user-input on ICT deployment for SCM in the enterprises as well as the quantitative inputs. In the initial stages, an investigation specifically meant to validate the positive influence in supply chain capabilities due to deployment of ICT was performed using system dynamics technique. Prior to the development of the questionnaire which contains open-ended questions and quantitative data points, the researcher had discussed with a cross-section of supply
chain industry practitioners and researchers. Inputs from industry experts were taken from both supply chain managers in manufacturing and services directly dealing in supply chain planning and execution as also professionals working on the automation side in ERP and software solutions for SCM. These deliberations were very useful in framing the questionnaire which was administered in 2 phases, first a pilot phase and then the final phase. Both semi-structured interviews for filling the questionnaire as well as online means were employed for administering it. The personal nature of the initial structured and semi-structured interviews during the pilot phase provided insights into the study as also validation of the metrics. And also understand respondents’ point of view with some valuable inputs coming like the fact that the respondent needs to be very well-versed in supply chain concepts or the fact that almost 20 minutes are needed to fill the questionnaire and the like. The pilot questionnaire and systems dynamics investigation were employed primarily for face validity.

In later stages, panel workshops and focus groups were also employed targeted at academic and industry professionals with experience working on supply chain projects and ERP or supply chain software solutions. Snowball sampling was employed and support for the survey was enlisted from Indian Institute of Materials Management, MSME Development Institute (DI), CIO Forum of Computer Society of India (CSI), Institute for Supply Chain Management (ISM), Coimbatore District Small and Medium Scale industries association (CODISSIA) and Coimbatore Management Association (CMA), all of whom, have a large member and subscriber base. More than a thousand emails were sent with the Google Form link of the survey using the good offices and networks of these industry associations and professional bodies.

After getting a turnaround of over 200 respondents in terms of filling the Google form with a survey questionnaire, analysis using Structural Equation Modeling (SEM) method was used. These respondents were SCM professionals in sectors such as manufacturing, services, MSMEs, international companies as well as SCM/ERP professionals working as domain experts in IT and service companies. SEM methodology was selected because of the fact that the supply chain performance constructs used for the proposed model are not directly measurable; they are measured through component measurable variables. SEM is commonly justified because of its capacity to attribute connections between non-measured variables from measured variables (Raghuram & Saleeshya, 2021; Nazempour et al. 2018; Cheng and Chen, 2016; Singh et. al. 2014; Singh et. al. 2013). Another advantage is that SEM evaluates the manifold and interconnected dependency in a single iteration. Confirmatory Factor Analysis (CFA) was employed to validate the latent variables from our proposed model. From these latent variables, an assessment model on benefits of ICT in SCM has been developed. The factor loadings associated with every measurement variable to the latent variables are explored through SEM.

5. EMPIRICAL MODELING USING SEM

An empirical model for measurement of ICT impact in SCM has been proposed based on the SCOR model. The model is based on exogenous & endogenous and latent & measured variables. Exogenous variables are independent with ICT Deployment as the exogenous latent variables and ICT Advances (Tools) & ICT Alignment chosen as exogenous measured variables. This is based on theoretical foundation and validated through expert opinion (Nair & Anbuudayasankar, 2016). Endogenous variables are dependent variables. Five latent endogenous factors were identified, viz., responsiveness, reliability, cost, agility and asset management efficiency for measuring ICT impact on SCM (Table 1). These were adopted from SCOR model performance indicators and Level I metrics. These were also validated through expert opinion and research literature. For these 5 factors, 13 measurable endogenous factors are also defined in SCOR and these were used on a multivariate scale for studying the ICT impact. These latent factors were linked to the measurement variables to develop the empirical model of supply chain. The exogenous and endogenous latent and measurement variables from SCOR (APICS, 2015). Industry validation of the adoption and usage of these supply chain performance constructs was also observed from companies like Walmart, Dell, Zara, Toyota and Flipkart. The
structural model is shown in Figure 1 in which all $\lambda$ are factor loadings, $\delta$ are measurement errors and $\gamma$ are regression weights.

6. RESULTS AND DISCUSSION

The suggested SEM causal model is given below in Figure 2. An empirical model for measurement of ICT Impact in SCM can be depicted as a mathematical model, depicting the causal association amongst the independent/measurable variables and the dependent/latent variables, both endogenous and exogenous and a structural model, depicting the causative association between the dependent variables. These theoretical relationships, both causal and correlational, can be tested and validated by SEM. The relationships observed in this theoretical model are depicted in the form of a path diagram in LISREL software which is used for analyzing the theoretical model as shown in Figure 1. The survey data collected is opened through integrated software called PRELIS. This is utilized for confirmatory data study estimating the factor loadings and fit metrics.

This model was further scrutinized using SEM and its fit metrics, viz., $\chi^2$, $\chi^2$/df, RMSEA & other indices and factor loadings were found to be within threshold limits shown below in Tables 2 and 3, thus validating the empirical model (Schreiber et al, 2006) and hypothesis on ICT deployment impacting the SCOR performance indicators.

None of the factor loadings are greater than 1 with most of them near 0.5 and above almost all the error variance are non-negative and this gives the preliminary fit criteria. All t-values in Table 3 are well above the threshold of 1.96 to be statistically significant. With respect to the error variances in Table 3, almost all the error variances are non-negative except two non-significant and small negative values which are Heywood cases. Heywood cases occur when there is only one measured variable for the latent variables and can be prevented by each latent variable defined by at least 3, and preferably 4, variables (Bagozzi & Yi, 1988). As per theoretical foundations of our model based on SCOR, performance constructs namely cost and responsiveness have only one measured variable. In future research, more measured factors can be added to these latent variables.

This research result using SEM validates the empirical model on ICT deployment for SCM as also hypothesis statements based on the impact of ICT deployment on SCOR performance constructs. The

| Endogenous Latent Variable | Endogenous Measured Variables |
|---------------------------|------------------------------|
| Reliability (X1)          | • Complete Delivery (CD)     |
|                           | • On-time Delivery (OD)      |
|                           | • Accurate Documentation (AD)|
|                           | • No Damage (ND)             |
| Responsiveness (X2)       | • Order Fulfillment Cycle Time (OCT)|
| Agility (X3)              | • Upside Supply Chain Flexibility (UPCA)|
|                           | • Upside Supply Chain Adaptability (UPSA)|
|                           | • Downside Supply Chain Adaptability (DSCA)|
|                           | • Overall Value at Risk (Risk)|
| Costs (X4)                | • Total Cost to Serve (Cost)|
| Asset Management Efficiency (X5) | • Cash to Cash Cycle Time (CCR)|
|                           | • Return on Supply Chain Assets (RFA)|
|                           | • Return on Working Capital (ROW)|

| Exogenous Latent Variable | Exogenous Measured Variables |
|---------------------------|------------------------------|
| ICT Deployment (Y)        | • ICT Advances/Tools (Impact)|
|                           | • ICT Alignment (Alignment)|

| Exogenous Measured Variables | Endogenous Measured Variables |
|------------------------------|------------------------------|
| ICT Advances/Tools (Impact)  | Reliability (X1)             |
| ICT Alignment (Alignment)    | Responsiveness (X2)          |
| ICT Deployment (Y)           | Agility (X3)                 |
| ICT Alignment (Alignment)    | Costs (X4)                   |
| ICT Deployment (Y)           | Asset Management Efficiency (X5) | • Cash to Cash Cycle Time (CCR)|
| ICT Alignment (Alignment)    | Exogenous Measured Variables | • Return on Supply Chain Assets (RFA)|
| ICT Deployment (Y)           | Exogenous Measured Variables | • Return on Working Capital (ROW)|
| ICT Alignment (Alignment)    | Exogenous Measured Variables | ICT Advances/Tools (Impact)|
Figure 1. Proposed Structural Equation (SEM) Causal Model on benefits of ICT for SCM

Figure 2. Path Diagram from LISREL
model constructs will be used to architect the capability index using methods like AHP & balanced scorecard (Sudarshan et al., 2019).

A study on developing a strategy for healthcare logistics performance based on the Health Metric Network framework tool points out that IT management is an important KPI for logistics performance (Kritchanchai et al., 2017). Another theoretical research model integrates 5 factors namely Information Technology Integration (IT), Inter-organizational Trust (TR), Relational Governance (RG), Transaction Cost (TC), and Supply Chain Performance (PE). This theoretical model clarifies the intricate relationships between the five factors by positioning two common resources for the

| Metric | Obtained Values | Ideal Values |
|--------|----------------|--------------|
| chi-square - χ² | 101.39 | Smaller the better |
| degrees of freedom – df | 75 | |
| Normed chi-square - χ²/df | 1.351 | < 3 |
| Root Mean Square Error of Approximation - RMSEA | 0.046 | < 0.05 |
| 90% CI for RMSEA | 0.0179; 0.0669 | < 0.05 lower limit |
| Root Mean Square Residual - RMR | 0.039 | < 0.05 |
| Normed Fit Index – NFI | 0.97 | > 0.9 |
| Non-Normed Fit Index – NNFI | 0.98 | > 0.9 |
| Comparative Fit Index - CFI | 0.99 | > 0.9 |
| Goodness of Fit Index – GFI | 0.92 | 1 is perfect fit and value varies from 0 to 1 |
| Adjusted Goodness of Fit Index - AGFI | 0.86 | 1 is perfect fit and value varies from 0 to 1 |

| Construct | Items | Standardized loadings | Error | t-value |
|-----------|-------|-----------------------|-------|---------|
| Reliability | CD | 0.456 | 0.13 | 11.942 |
| | OD | 0.529 | 0.09 | 13.713 |
| | AD | 0.473 | 0.18 | 11.033 |
| | ND | 0.501 | 0.33 | 9.268 |
| Asset Management Efficiency | CCR | 0.592 | 0.15 | 13.262 |
| | RFA | 0.625 | 0.18 | 13.041 |
| | ROWC | 0.489 | 0.17 | 11.516 |
| Agility | UPCA | 0.456 | 0.24 | 9.957 |
| | UPSA | 0.514 | 0.21 | 11.262 |
| | DSCA | 0.515 | 0.16 | 12.145 |
| | Risk | 0.468 | 0.22 | 10.394 |
| Responsiveness | OCT | 0.699 | -0.09 | 8.24 |
| Cost | Cost | 0.872 | -0.02 | 3.943 |
supply chain: Inter-organizational Trust and IT, as the independent variables that influence outcome measures: performance and reduction in transaction costs (Singh & Teng, 2016). Not many research investigations were seen on similar lines in the past.

However, in terms of comparison of the research findings with respect to recent investigations, the area is dominated by similar MCDM (Multiple-criteria decision making) based research methods and firms-level studies (Khan et al, 2021[2]). A recent paper reports a similar work applied for SMEs in Mexico in which SEM is employed with 4 latent variables related to ICT applied in supply chain namely Technological innovation, information management, and information availability as independent variables, and operating benefits gained as a dependent variable (Pérez-López et al, 2021). Interestingly, SCOR version 12 which is the latest version of SCOR considers digital capabilities mapped to all processes of SCOR model. SCOR digital is compatible and connected to Digital Capabilities Model (DCM) for SCM by Deloitte & ASCM. Elements of this evolving model which resonate with this research investigation include connected customer, dynamic fulfillment, synchronized planning, intelligent supply, smart operations and product development (APICS, 2017).

7. FUTURE RESEARCH DIRECTIONS

As such, the SEM analysis of this research has validated the proposed empirical model and various performance indicators in the framework for benefits of ICT in SCM. The next step is to use these supply chain performance indicators to architect an ICT Capability Index for SCM as a universal benchmark for measuring the impact, effectiveness and benefits of ICT enablement in SCM. Based on the multiple indicators of ICT impact on SCM, this ICT Capability Index is one that requires Multi-Criteria Decision-Making (MCDM).

This study has focused primarily on strategic supply chain metrics or level I metrics as per the SCOR model. There is ample scope to extend the investigation into level II measures which are diagnostics of strategic metrics and level III measures which are context or sector-specific. There is also scope to expand the investigation focusing on SCOR business processes such as planning, sourcing, making, delivering, returning and enabling. A cluster-based or sector-based analysis approach can also be considered as an extension to the research. There are avenues to fine-tune the scope of the investigation to focus not only on specific sectors or verticals but also specific ICT tools and specific geographies. For example, impact of big data analytics on automobile industry in South India, Cyber Physical Systems in retail sector in metros etc.

8. MANAGERIAL IMPLICATIONS

There is a visible current trend of automation and data exchange in manufacturing technologies which is referred to as Industry 4.0. Industry 4.0 fosters what has been called a “smart factory” and also Industrial IoT (IIoT) and this is rapidly impacting all industry sectors and verticals. McKinsey estimates the Industry 4.0 value creation potential to be US$ 3.7 trillion by 2025. The Port of Seville in Spain uses a Cloud cum IoT system designed to optimize, manage and monitor container transport operations along an intermodal corridor, combining rail scheduling and inland vessel navigation (Munuzuri et al, 2020). Covid-19 pandemic has accelerated the need for Industry 4.0, digitalization and embracing of ICT not only for supply chain but also all aspects of the enterprise.

Digital is the new core of business. Today, 90% enterprises are increasing digital footprint which includes ICT enabled SCM which will result in sustainable, green, circular and resilient supply chains. This research assumes significance in this context of developing Digital Capabilities Model (DCM) for SCM. This framework provides a universal benchmark that provides enterprises with strategic choices for their investment in ICT as also choice of ICT tool and understanding success factors and operational challenges for adoption of these tools. Measurement of the ICT impact on SCM aids decision-making and helps managers to identify targets; track and benchmark progress;
align their business; assess, compare and share best practices and improve stake-holder relationships and governance. Managers are able to assess to what extent ICT and digital technologies matters to them in their enterprises and how it might transform their supply chains by leveraging ICT and digitizing their operations.

9. CONCLUSION

Covid-19 pandemic has accelerated the need for Industry 4.0, digitalization and embracing of ICT not only for supply chain but also all aspects of the enterprise. Today, 90% enterprises are increasing their digital footprint which includes ICT enabled SCM, which will result in sustainable, green, circular and resilient supply chains. The ICT advantage for SCM holds immense potential and savings for industry, be it large enterprises or MSME. This becomes all the more relevant considering the fact that annual global supply chain losses run into billions of dollars. Developing digital capabilities for SCM has become inevitable.

While most researchers and industry practitioners are unanimous about the fact that ICT positively impacts supply chain capabilities and performance by way of many frameworks having been proposed, there is an identified gap in terms of rubrics, constructs, assessment frameworks and metrics of these ICT benefits and capabilities in SCM. A novel research performed in this direction is an empirical investigation into the positive impact of ICT deployment in SCM and validation of a proposed empirical model using SEM. This model can be seamlessly dovetailed into the universally accepted and popular APICS SCOR model as the constructs are based on its level I metrics/indicators. The next step is to use these supply chain performance indicators to architect an ICT Capability Index for SCM as a universal benchmark for measuring the impact, effectiveness and benefits of ICT enablement to form an assessment framework. This ICT Capability Index is one that requires Multi-Criteria Decision-Making (MCDM) and can be used by any enterprises, irrespective of industry verticals or sectors.

The managerial implications of this investigation is that measurement of the ICT impact on SCM will aid decision-making and help policy-makers to identify targets; track and benchmark progress; align their business; assess, compare and share best practices and improve stake-holder relationships and governance. Enterprises need to assess to what extent ICT and digital technologies matters to them and how it might transform their supply chains by leveraging ICT and digitizing their operations. They can use this framework to assess to what extent digital technologies and ICT matters to them and how it might transform their supply chains and business models and also affect financial performance and diagnostics. In terms of comparison of the research findings with respect to recent investigations, the area is dominated by similar MCDM (Multiple-criteria decision making) based research methods. Interestingly, SCOR version 12 which is the latest version of SCOR considers digital capabilities mapped to all processes of SCOR model and this research investigation resonates with this state-of-the-art supply chain model.
REFERENCES

APICS. (2015). Supply Chain Operations Reference Model, Revision 11.0. Retrieved from https://docs.huihoo.com/scm/supply-chain-operations-reference-model-r11.0.pdf

APICS. (2017). Supply Chain Operations Reference Model, Revision 12.0. Retrieved from http://www.apics.org/docs/default-source/scor-training/scor-v12-0-framework-introduction.pdf?sfvrsn=2

Bagozzi, R. P., & Yi, Y. (2012). Specification, evaluation, and interpretation of structural equation models. Journal of the Academy of Marketing Science, 40(1), 8–34. doi:10.1007/s11747-011-0278-x

Birkel, H. S., & Hartmann, E. (2019). Impact of IoT challenges and risks for SCM. Supply Chain Management, 24(1), 39–61. doi:10.1108/SCM-03-2018-0142

Cheng, J.-H., & Chen, M.-C. (2016). Influence of Transactional and Moral Orientations on Innovation Performance in Supply Chains. International Journal of Information Systems and Supply Chain Management, 9(2), 61–77. doi:10.4018/IJISSCM.2016040104

Christopher, M. (2016). Logistics & Supply Chain Management. Pearson.

de Barros, A. P., Ishikiriyama, C. S., Peres, R. C., & Gomes, C. F. S. (2015). Processes and benefits of the application of information technology in supply chain management: An analysis of the literature. Procedia Computer Science, 55, 698–705. doi:10.1016/j.procs.2015.07.077

Dong, S., Xu, S. X., & Zhu, K. X. (2009). Information technology in supply chains: The value of IT-enabled resources under competition. Information Systems Research, 20(1), 18–32. doi:10.1287/isre.1080.0195

Ferrantino, M. J., & Koten, E. E. (2019). Understanding Supply Chain 4.0 and its potential impact on global value chains. Global Value Chain Development Report 2019, 103. Retrieved from https://www.wto.org/english/res_e/booksp_e/gvc_dev_report_2019_e_ch5.pdf

Gunasekaran, A., & Kobu, B. (2007). Performance measures and metrics in logistics and supply chain management: A review of recent literature (1995–2004) for research and applications. International Journal of Production Research, 45(12), 2819–2840. doi:10.1080/00207540600806513

Gunasekaran, A., Subramanian, N., & Papadopoulos, T. (2017). Information technology for competitive advantage within logistics and supply chains: A review. Transportation Research Part E, Logistics and Transportation Review, 99, 14–33. doi:10.1016/j.tre.2016.12.008

Gunasekharan, A., & Ngai, E. W. T. (2004). Virtual Supply Chain Management. Production Planning and Control, 15(6), 584–595. doi:10.1080/09537280412331283955

Hasibuan, A., Arfah, M., Parinduri, L., Hernawati, T., Harahap, B., Sibuea, S. R., & Sulaiman, O. K. (2018, April). Performance analysis of Supply Chain Management with Supply Chain Operation reference model. Journal of Physics: Conference Series, 1007(1), 012029. doi:10.1088/1742-6596/1007/1/012029

Hassini, E., Surti, C., & Searcy, C. (2012). A literature review and a case study of sustainable supply chains with a focus on metrics. International Journal of Production Economics, 140(1), 69–82. doi:10.1016/j.ijpe.2012.01.042

Katiyar, R., Barua, M. K., & Meena, P. L. (2017). Analyzing the Interactions Among the Barriers of Supply Chain Performance Measurement: An ISM with Fuzzy MICMAC Approach. Global Business Review, 19(1), 48–68. doi:10.1177/097215091773283

Khan, S. A., Chaabane, A., & Dweiri, F. (2019). A knowledge-based system for overall supply chain performance evaluation: A multi-criteria decision making approach. Supply Chain Management, 24(3), 377–396. Advance online publication. doi:10.1108/SCM-06-2017-0197

Khan, S. A. R., & Yu, Z. (2021). Assessing the eco-environmental performance: An PLS-SEM approach with a practice-based view. International Journal of Logistics Research and Applications, 24(3), 303–321. doi:10.1080/13675567.2020.1754773

Khan, S. A. R., Yu, Z., Golpira, H., Sharif, A., & Mardani, A. (2021). A state-of-the-art review and meta-analysis on sustainable supply chain management: Future research directions. Journal of Cleaner Production, 278, 123357. Advance online publication. doi:10.1016/j.jclepro.2020.123357
International Journal of Information Systems and Supply Chain Management
Volume 15 • Issue 1

Khan, S.A.R., Yu, Z., Sarwat, S., Godil, D.I., Amin, S., & Shuaat, S. (2021). The role of blockchain technology in circular economy practices to improve organizational performance, *International Journal of Logistics Research and Applications*. 10.1080/13675567.2021.1872512

Koot, M., Mes, M. R. K., & Jacob, M. E. (2021). A systematic literature review of supply chain decision making supported by the Internet of Things and Big Data Analytics. *Computers & Industrial Engineering*, 154, 107076. Advance online publication. doi:10.1016/j.cie.2020.107076

Kritchanchai, D., Hoeur, S., & Engelseth, P. (2017). Develop a strategy for improving healthcare logistics performance, *Supply Chain Forum. International Journal (Toronto, Ont.)*, 19(1), 55–69.

Kumar, A., Singh, R. K., & Modgil, S. (2020). Exploring the relationship between ICT, SCM practices and organizational performance in agri-food supply chain. *Benchmarking*, 27(3), 1003–1041. doi:10.1108/BIJ-11-2019-0500

Lima-Junior, F. R., & Carpinetti, L. C. R. (2017). Quantitative models for supply chain performance evaluation: A literature review. *Computers & Industrial Engineering*, 113, 333–346. doi:10.1016/j.cie.2017.09.022

Mihardjo, L. W. W., Sasmoko, S., Alamsyah, F., & Elidjen, E. (2020). Maximizing co-creation strategy through integration of distinctive capabilities and customer experiences in supply chain management. *Uncertain Supply Chain Management*, 8(1), 187–196. doi:10.5267/j.uscm.2019.7.005

Mufüzuri, J., Onieva, L., Cortés, P., & Guadix, J. (2020). Using IoT data and applications to improve port-based intermodal supply chains. *Computers & Industrial Engineering*, 139, 105668. doi:10.1016/j.cie.2019.01.042

Nair, P. R., & Anbuudayasankar, S. P. (2016). An investigation on the benefits of ICT deployment in supply chain management (SCM). *Indian Journal of Science and Technology*, 9(30), 1–7. doi:10.17485/jfst/2016/v9i30/99063

Nazempour, R., Yang, J., & Waheed, A. (2018). An Empirical Study to Understand the Effect of Supply Chain Agility on Organizational Operational Performance: SC Agility and Organizational Performance. *International Journal of Information Systems and Supply Chain Management*, 11(4), 1–20. doi:10.4018/IJISSCM.2018100101

Pérez-López, R. J., Olguín-Tiznado, J. E., García-Alcaraz, J. L., Mjaro-Magaña, M., Camargo-Wilson, C., & López-Barreras, J. A. (2021). Integrating and controlling ICT implementation in the supply chain: The SME experience from baja California. *Mathematics*, 9(11), 1234. doi:10.3390/math9111234

Prajogo, D., & Olhager, J. (2012). Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration. *International Journal of Production Economics*, 135(1), 514–522. doi:10.1016/j.ijpe.2011.09.001

Raghuram, P., & Saleeshya, P. G. (2016). Assessing the responsiveness of supply chain - SEM based approach. *International Journal of Logistics Systems and Management*, 25(4), 558–579. doi:10.1504/IJLSM.2016.080253

Raghuram, P., & Saleeshya, P. G. (2021). Responsiveness Model of Textile Supply Chain – A Structural Equation Modeling based Investigation. *International Journal of Services and Operations Management*, 38(3), 419–440. doi:10.1504/IJSOM.2021.113605

Sardana, G. D. (2009). Exploring the performance of a responsive supply chain. *Supply Chain Forum: An International Journal*, 10(2), 38-39.

Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, J. (2006). Reporting structural equation modeling and confirmatory factor analysis results: A review. *The Journal of Educational Research*, 99(6), 323–338. doi:10.3200/JOER.99.6.323-338

Singh, A., & Teng, J. T. C. (2016). Enhancing supply chain outcomes through Information Technology and Trust. *Computers in Human Behavior*, 54, 290–300. doi:10.1016/j.chb.2015.07.051

Singh, R., Sandhu, S., Metri, B. A., & Kaur, R. (2013). Modeling Supply Chain Performance: A Structural Equation Approach. *International Journal of Information Systems and Supply Chain Management*, 6(4), 18–41. doi:10.4018/ijisscm.2013100102

Singh, R., Sandhu, S., Metri, B. A., & Kaur, R. (2014). Supply Chain Management Practices, Competitive Advantage and Organizational Performance: A Confirmatory Factor Model. *International Journal of Information Systems and Supply Chain Management*, 7(2), 22–46. doi:10.4018/ijisscm.2014040102
Sudarshan, S. V., Priyadarshuan, A., & Anbuudayasankar, S. P. (2019). Analysis of the barriers in implementing green supply chain management (GSCM) practices: A hybrid approach. *IOP Conference Series. Materials Science and Engineering, 577*(1), 012005. doi:10.1088/1757-899X/577/1/012005

Van Hoek, R., Aronsson, H., Auramo, J., Kauremaa, J., & Tanskanen, K. (2005). Benefits of IT in supply chain management: An explorative study of progressive companies. *International Journal of Physical Distribution & Logistics Management, 35*(2), 82–100. doi:10.1108/09600030510590282

Wu, F., Yeniyurt, S., Kim, D., & Cavusgil, S. T. (2006). The impact of information technology on supply chain capabilities and firm performance: A resource-based view. *Industrial Marketing Management, 35*(4), 493–504. doi:10.1016/j.indmarman.2005.05.003

Xue, J., Li, G., & Li, N. (2021). Does green and sustainable engagement benefit online platforms in supply chains? The role of green and public concern. *International Journal of Logistics Research and Applications*. doi:10.1080/13675567.2021.1914564

---

S.P. Anbuudayasankar is a Faculty of Mechanical Engineering Department at Amrita Vishwa Vidyapeetham, India. He holds a Bachelor’s in Mechanical Engineering, a Master’s in Industrial Engineering and Management in Production. He holds a Doctorate in Supply Chain and Logistics and his thesis was awarded the Best PhD thesis. His research interests include meta-heuristics, optimisation multi criteria decision making and supply chain, location and allocation problems and also social sciences. He has published several papers in national and international journals and conferences.

P. Raghuram is an Assistant Professor of Mechanical Engineering at the Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Coimbatore, India. He received his PhD in Supply Chain Responsiveness from the Amrita Vishwa Vidyapeetham. His areas of interest in teaching and research are mainly focused on supply chain management, responsiveness and risks in supply chain, enterprise operational strategies, lean manufacturing, and data analytics.