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Anti-Disruptive Effect of Industry 4.0 on SCM: A Qualitative Study on Selected Indian Construction Companies

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***Abstract* – Rationale: Growing expectations and need of stakeholders followed with technological advancements at different ends of the Supply Chain (SC) are making the entire chain quite complex, and prone to disruptions and indecisive. To manage several aspects associated with the continuity of business processes, it become imperative to manage the supply chain risks associated with disruptions implicitly and explicitly. In this context interest of the academicians, researchers and industrialists for Industry 4.0 and related technologies for managing the disruptions of SC is burgeoning. The principal objective of the present research work is to qualitatively assess the relative effect of the Industry 4.0 tools and technologies on the SC visibility and flexibility which leads into making the SC more repressible and robust.**

Methodology: The research work was carried out in two different stages. In first stage extensive review was performed over the studies related with the disruptions in SC to identify the major challenging aspects and in consequent section analysis is presented.

Conclusion: This research work confirms that Industry 4.0 tools and technologies are effective in building a resilient and robust SC at different stages. It is also noticed that Industry 4.0 tools and technology applications result into more explicit and implicit benefits to the SC in pre-turmoil and reclamation stage.

Practical Contribution: The research work may help to know about the key areas of the SC followed with the application of Industry 4.0 tools and technologies to make the SC more resilient and robust for continuity of business.

***Keywords* – Supply Chain, Industry 4.0, Business Continuity, Supply Chain Resilience, Disruption, Robustness, Tools and Technologies, Visibility**

I. INTRODUCTION

Streamlined business activities backed with advanced technology tools and applications are conceptualizing the future for the businesses and offering them the global reach and diversification. In order to ensure the supplies throughout the globe and to match the need of customers, businesses are expanding their SC. Hence, with the scale and scope of the SC the associated complexities had also been increased. Higher complexities associated with the SC lead into disruptions and hinders the regular operations of SC. Complexities associated with the SC can be natural as well as man-made such as the Covid-19 (Corona Virus Diseases, 2019), which was declared as the Global Pandemic by WHO on March 11, 2020 (Stecke & Kumar, 2009; Cucinotta & Vanelli, 2009). During the Covid-19 outbreak, it was noticed that the most of the supply chains were not prepared to manage the disruptions caused by outbreak. Hence, need of managing such disruptions effectively is identified by the companies, particularly for disruption never experienced before. Major set-back observed by companies was related with restricted movements and lack of accessibility to several facilities which were placed over the movement of raw material, finished goods and work-in-progress goods throughout the different supply chains (Stecke & Kumar, 2009). Lack of access to distribution centers, inventory houses, facility centers and other physical processes drive the need of regulating all physical processes through several means and channels particularly through twinning the digital, smart and real-time systems technologies of the physical world to integrate man, machine and others (Wang et al., 2016). This also drives the companies to reengineer the existing structure and methods of work.

On other side, in this dynamic world when uncertainties related with the demand and supply, risks associated with supplies, increasing competition, ever changing customer

expectations, inability of organizations of process integration with technological advancements, time constraints in delivery etc., are some major hindrances for organizations to manage the visibility and excellence of supply chain. Industry 4.0 tools and technologies with horizontal and vertical integration (Alcacer & Cruz-Machado, 2019) practices conceptualized with the background of real-time system, intelligent and flexible manufacturing, secured data transmission, flexible and visible SC with end to end integration (Bag et al., 2018), customer centric product customization (Thoben et al., 2017; Li et al., 2017), etc. are driving technology driven intelligent SC which overcome the challenges posed by aforementioned hindrances.

Principally, the Industry 4.0 framework ensures the continuous and timely flow of the information to the holistic industrial functions and processes, particularly in supply chain, cross-industry production or manufacturing and supplies followed with the channeling of information at different intelligent systems (Wan et al., 2017; Wang et al., 2016). Industry 4.0 enabled digital world had made the Supply Chain Management more data or information intensive (Min, 2010; Huang & Huang, 2019) and emphasized over the need of real-time data to manage the disruption in order to mitigate the risks associated with the SC.

The role of Industry 4.0 tool and techniques such as Internet of Things, Cloud Computing, Big Data, Cyber Systems etc. (Lee et al., 2015; Lasi et al., 2014) in making the entire supply chain intelligent is quite imperative. These tools and techniques are helpful in predicting the risks and to identify the ways of making the SC more visible and flexible for business continuity and to regulate the losses to be incurred due to unanticipated disruptions. Industry 4.0 driven technology twinning with the conventional business and supply chain systems made the system rich and intelligent through transforming business value chains intelligence and for this the comprehensive integration of all the business processes with the stakeholders is required (Rashid & Tjahjono, 2016).

So, Industry 4.0 tools and technologies helps to manage the SC effectively through enabling the collaborative linkages and higher degree data channeling of the organization with its SC stakeholders namely customers, distributors, intermediary partners, suppliers etc. (Huang & Huang, 2019). Technologies such as Artificial Intelligence (AI), Neural Networks and Robotics, block chain, cloud computing, IoT, Machine Learning, Deep Learning, Data Analytics help to conceptualize intelligent supply system through different sets of experience and historical data. With the integration of Industry 4.0 tools and technologies system would become more intelligent and drive to draw the benefits of supply chain as value chain, as the technology enabled SC would not be limited with premediated business functions rather will help to draw optimum competitive advantages through technological means (Chen et al., 2009; Kumar et al., 2017). In order to draw the competitive advantage of advancement of Industry 4.0 continuous integration of technological development is mandatory (Rahman et al., 2020; Ku et al., 2020). Continuous advancement of the system makes the system more intelligent and flexible and helps to draw the timely optimal decision.

The content presentation of the research work starts with brief information over the SC disruptions followed with the need of supply chain visibility and flexibility to improve its resilience. In continuation, some specific Industry 4.0 tools and technologies namely Artificial Intelligence (AI), Block Chain, Internet of Things (IoT) etc. would be discussed with their applicability in making the Supply Chain resilient followed with the challenges faced during the course of implementation of aforementioned tools and technologies. In the next section of the research work results based on the study would be discussed followed with the conclusions and recommendation.

II. METHODOLOGY

The research methodology followed for this research work was based on the research steps recommended by Denyer and Tranfield (2009) for the systematic exploration of the subject area. The steps followed in the sequential form are:

- Defining the Research Objective(s),
- Defining Research Questions,
- Literature Exploration – Identifying the related studies,
- Data Extraction and Analysis, and
- Results and Findings.

1. Defining the Research Objective(s)

This step of the research process discusses the primary objective(s) of the research work. The principle aim of the research is to qualitatively assess the roles of Industry 4.0 tools and technologies in making the supply chain more resilient through improved visibility and flexibility particularly in context to selected construction companies.

2. Defining the Research Question(s)

Research questions to be answered through research work (Seuring & Muller, 2008; Denyer & Tranfield, 2009; Scheidegger et al., 2018). Considering the above stated research objective following research questions would be under evaluation focus:

Research Question 1:

What are the reasons of disruptions in the SC and how the disruptions are associated with the process continuity followed with its negative effect?

Research Question 2:

How the SC resilience can be attained through visibility and flexibility?

Research Question 3:

What is the role of Industry 4.0 technologies and tools in SC resilience? How the SC and business continuity can be maintained through advanced technologies?

Research Question 4:

What framework or method to be used to achieve the SC visibility?

3. Literature Exploration

Identifying Related Studies: Research work started with reading the relevant articles, papers, blogs published either online or offline. For this research work, cases, research papers and articles published in reputed academic databases such as Scopus, ABDC, EBSCO, Academia, RG were chosen for subject detailing. Some specific keywords used to identify the right papers under the study scope were Supply Chain, Industry 4.0, Resilience, Industry 4.0 tools and technologies, Disruptions, Construction Companies, Intelligent System, and Value Chains etc. Out of the different papers studied during the research work 152 (71.36%) different research papers of standard published by authentic publishers were studied in detailed manner to specific information and literature extraction.

4. Data Extraction and Analysis

Deep understanding developed from the reviewed studies were based on different dimensions, scope and variables (Rai et al., 2006; Fabbe-Costes & Jahre, 2008) under two broad attributes namely Technology Attribute and Supply Chain Attributes pertained to the construction companies. The basic conceptual framework for the industry 4.0 tools and technologies enabled SC which leads into SC visibility and flexibility as the final result of SC resilience was based on grouping criterions.

5. Results and Findings

Results were obtained from the primary data captured through questionnaire and interviewing the executives involved in the SC process of the selected construction companies. To draw conclusions qualitative analysis was performed and information accumulated was tabulated for the interpretation purpose.

III. SAMPLING DETAILS

For this research work sample determination was based on the professionals associated with supply chain and managing the risks associated with disruptions in different steps and processes of the supply chain. It was ensured during sampling of SC professionals that professionals should carry good experience in managing the SC risks associated with the different disruptions and extent of Industry 4.0 tools and techniques used to manage the risks association with disruptions in the SC of their companies (Gottlieb et al., 2019).

Professionals of the following construction companies were chosen for the study purpose.

Table 1: Sampled Construction Companies

S. No	Construction Companies
1.	L&T Construction
2.	Gammon engineers and contractors Pvt. Ltd.
3.	JMC Projects India Ltd.
4.	Afcons Infrastructure Ltd.
5.	Hindustan Construction Company
6.	Tata Projects
7.	Shapoorji Pallonji Co. Ltd.
8.	S.P. Singhla
9.	KEC international Ltd.
10.	Patel Engineering

Above mentioned construction companies are large in scale and have complex supply chain and due to large scale following the advancements of Industry 4.0 SC of the construction companies are prone to disruptions. The SC professionals of the above-mentioned construction companies were approached through physical meet and their responses were recorded through a well-structured questionnaire developed with the help of research guide, SC professionals, review of literature, and other analytical methods. Further,

Analysis over the response set was done in detailed to find the different inferences through analysis. Sampled number of SC professionals or experts from the tabulated construction companies in number were 20 (Only 2 from each company), such method of sampling was also followed by Gottlieb et al., 2019; Benny, 2020 in their case based studies performed over the similar domain. Most common positions of the sampled supply chain professionals of the sampled construction companied were Supply Chain and Logistics Manager, Supply Chain and Unit Manager and Business Process Manager.

IV. REVIEW OF RELATED STUDIES

This section will present the literature presenting the exponential growth, visibility and flexibility observed by the supply chain domains due to integration of Industry 4.0 tools and technologies followed with the disruption for the SC. Studies were categorized in following sections:

1. A.Studies Related Industry 4.0 Tool and Technologies and Integration with SC

Digital technologies enabled systems encapsulated with internet technologies, automated and intelligent systems have developed the multi-dimensional possibilities in men-machine interaction and communication channel. System empowered with interconnected networks of men and machines had made the organizational system visible, agile and flexible and offering resilience against the risks caused by disruptions. Integrating and imparting the concept of such interconnected digital technology enabled system and processes in the different organizational processes such as Supply Chain is executed under the

Industry 4.0 technology transformation age (Tjahjono et al., 2017).

Digitalization and technology integration in the different processes and networks of SC led the system capacity of surviving in different disruptions states through making the system resilient and agile. In Industry 4.0 enabled technological development different information and communication technologies and digital technologies get intertwined with the existing processes of SC to improve its overall agility and resiliency (Ghadge et al., 2020). Industry 4.0 encompasses technologies like Blockchain, Big Data Analytics, Augmented / Virtual Reality, Cloud Computing, Artificial Intelligence, IoT, Simulation, Robotics, Smart Machines, Addictive Manufacturing etc. All the aforementioned technologies help in digitizing the entire supply chain and ensures agility, timeliness, customization, through the proper channeling of information procured from multiple end points of the organization and process. Integrating Industry 4.0 technologies with the SC in total helps in planning, monitoring, controlling, innovating, tracing the momentum of the operations through visibility, flexibility and agility (Ghadge et al., 2020). Industry 4.0 tools and technologies also helps in nearly accurate forecasting for the raw material and inventory management and through simulation helps in planning different aspects of SC. It also offers transparency at different stages and ensures the availability of the data which let get the benefits of improved performance of SC as value chain with the minimal risk effects (Luthra & Mangla, 2018).

Major components of Industry 4.0 are Internet based services and CPS, multi-agent system, man-machine interoperability, forecasting and estimating the effect of risk on the business continuity and SC, real-time technologies, Big Data management, robotics and atomization for process optimization, timely and inter-disciplinary data accessibility, distributed storage of data or cloud technologies (Hofmann et al., 2019). Industry 4.0 tools and technologies advances the visibility and flexibility through interconnecting and streamlining the business and SC components through different ICTs and real-time data driven machines. Technology enabling also ensures decentralization, mobility and obtainment of different sets of information at every end of the SC (Okwu & Tartibu, 2020).

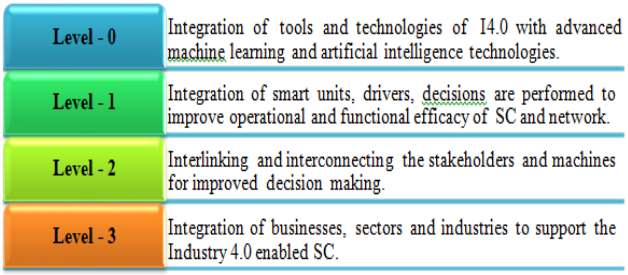

Figure 1: 4-L Framework of Smart Hierarchical SC with ICT

A four level framework of smart hierarchical supply chain encapsulating ICT technologies and digital technology enabled frameworks for smart SC was presented by Zhang et al. (2022). In the first level of (L-0) incorporates the integrations of different tools and technologies of Industry 4.0 with advanced machine learning and artificial intelligence technologies. In second level (L-1) incorporation of smart units, smart drivers, smart decisions are performed to improve the operational and functional efficacy of SC and network. In third level (L-2) framework emphasized over interlinking and interconnecting the stakeholders and all the machines to improved decision making. In fourth level (L-3) framework emphasized over the integration of businesses, sectors and industries which can support the Industry 4.0 enabled SC. In totality the framework emphasizes over the development of Industry 4.0 enabled technological smartness derived from different ICT and hardware / software applications to transform the SC into value chain.

2. Studies Related with SC Disruptions

Supply Chain network of any organizational system is not limited with the supplies or distribution of the products but also extends its activities through information channeling. Hence, the network of SC incorporates manufacturer, suppliers, inventory houses, retailer, distributors, entities, information, resources and the different processes involved in moving the products and information from the manufacturer to the end user.

The process of SC initiates with the procurement of raw materials, creating inventory of raw material, processing the raw material to the manufacturing process (Work in Progress), finished goods and distribution of finished goods through different channels till end user. During the entire process the SC network may observe several disruptions due to several controllable and uncontrollable factors and ultimately disruptions may lead into risks to SC and business continuity. The existence of disruptions and driven risks sustains throughout the existence of the supply chain, and fragility of SC is associated with globalization and other global/ local advancements (Snyder & Shen, 2007).

It is quite obvious that SC cannot develop the immunity against to the disruptions, as the SC practices and processes are dynamic by nature and the scale of the SC network may observe any kind of disruption due to dynamicity at any end (Flynn, 2010). The unmanaged disruptions lead into risks and losses, so it is recommended to manage the disruptions associated SC (Snyder & Shen, 2007).

Novack (Bigcommerce, 2020) mentioned that there are many reasons for the SC disruptions and broadly categorized disruptions on the basis of frequency of occurrence and severity. The major causes of the disruptions in SC are:

Environmental Disasters

Real time monitoring of the eco-system is needful to ensure the impact of risk over the business continuity (Lin et al., 2017).

Pandemics

Due to Covid-19 outbreak approximately 70% of the companies around the globe have observed negative impact on their businesses (Accenture, 2019).

Logistics and Transportation Failures

Logistics is not limited up to the delivery of the product, it need to be streamlined and intelligent (Barreto et al., 2017; Harris et al., 2015) with intelligent or smart warehouses (Liu et al., 2018) for timely replenishment.

Political and Economic Instability

Complex issues associated with the political and economic disruptions may cause diverse risks to the business continuity and role of advanced technologies to build the compatibility and sustainability is inevitable (Luthra & Mangla, 2018).

Cyber Issues

A well-structured threat defending cyber-physical network to drive all the virtual networks of the SC in streamlined manner (Mladineo et al., 2017).

Price Fluctuations

Price optimization from starting end to the terminating end of the SC helps to optimize the profitability. Digital technologies offer platforms with forecasting capacity for optimized SC (Rashid & Tjahjono, 2016).

Technological Shifts

Sharing of information in different processes and amongst stakeholders of SC and disruptions related with data communication and exchange need to be managed (Birkel & Hartmann, 2019)

Incorporating the above mentioned reasons several other factors also become the cause of SC disruptions and lead into associated risks for the business well-being and continuity, and it is one of the essential requirements for the companies to manage and mitigate the risks associated with disruptions (Benny, 2020).

3. Industry 4.0 and SC Resilience

Integration of digital technologies had made the supply chain network global, other than the technological upgrade, several political and economic factors have also made the SC network globalized. Market dynamics which had shorten the life cycle of products and services and accelerated customer expectations resulting into complexities for the SC followed with economic negativity. In order to observe the minimal effect of the risks SC components must be highly correlated with the capacity to get back to the normal state (Ponomarov & Holcomb, 2009).

So, resiliency of the supply chain is one solution of the ensuring the effect of risks at its minimal. Resilient supply chain offers the competitive advantages through restoration of the normal functions and risk mitigation. Resiliency of the supply chain can be developed through making the SC visible and flexible. Otherwise, the resiliency of supply chain is multidisciplinary by nature. Interdisciplinary practices may incorporate:

SC environment should be agile to manage the unprecedented threats, risks, challenges for the business environment with the capacity to transform the risk or challenges into opportunity (Sharifi & Zhang, 1999).

Flexibility and Agility both are different, Agility drives versatility and adaptability and on other side flexibility is related with common and collaborative platform for the system (Swafford et al., 2008).

Developing the adaptive capability in SC for managing and recovering from unexpected events (Ponomarov & Holcomb, 2009).

Fast decision making can be ensured through the visible and flexible SC in case of any disruption. Visibility can be ensured at four parts for sensing, learning, coordinating and integrating (Wei & Wang, 2010).

Visible and shared operations, activities and information of SC strategy and patterns lead into more visibility to the SC and helps in effective and fast decision making (Caridi et al., 2014).

Flexibility and visibility in SC are aimed to reduce the negative effect caused by disruptions through streamlining the operations and activities (Mandal et al., 2016).

Flexibility can be strategic and manufacturing (Swafford et al., 2008). Strategic flexibility is related with managing the risk caused by economic and political disruptions through prompt and effective decision making (Grewal & Tansuhaj, 2001). Flexibility leads into minimizing the effect of risk caused by disruptions (Richey et al., 2009).

So, based on the aforementioned discussion, it is noticed that visibility, flexibility, and other interdisciplinary actions leads into resilient SC and ensures the continuity of business operation through reducing the effect of risk associated with disruptions. But, in order to manage the flexibility and visibility in SC, company has to apply several additional cost. So, it is recommended that a proper balance between the cost to be applied in the activities to make the SC flexible and visible need to be ensured (Ben-Daya et al., 2019).

V. DATA EXTRACTION AND ANALYSIS

1. Hypotheses Description

The above mentioned literature in the different sections leads into identifying several gaps and challenges posed by and for digital technologies particularly through the

tools and technologies of Industry 4.0 in different systems and processes of the Supply Chain. It was noticed from the review of literature that visibility and flexibility of SC are good indicators of risk management and disruption of SC can better be managed through advanced tools and technologies of the Industry 4.0. So, on the basis of different benefits and challenges of Industry 4.0 for Supply Chain following hypotheses were developed for the study purpose:

- **H01:** Risk factors associated with the Supply chain cannot be managed through visibility and flexibility.
- **Ha1:** Risk factors associated with the Supply chain can be managed through visibility and flexibility.
- **H02:** Managing disruptions through Industry 4.0 tools and technologies do not leads in more robust SC.
- **Ha2:** Managing disruptions through Industry 4.0 tools and technologies leads in more robust SC.

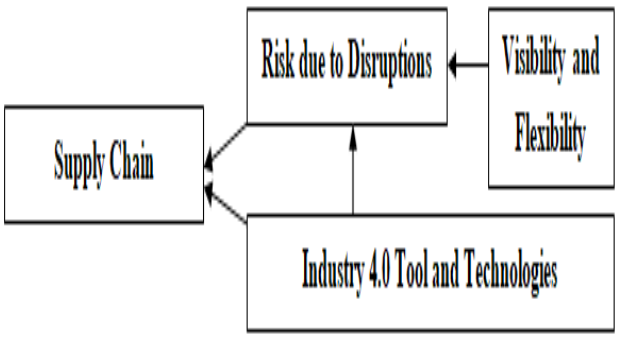

Figure 2: Hypothesis – Relationship between the Study Variables

These aforementioned hypotheses are based on inferences drawn from the literature associated with the effects of disruption on SC and contribution of advanced technologies in SC resilience.

2. Analysis

The purpose of this section is to validate and identify the role of Industry 4.0 tools and technologies in making SC more visible and flexible which in turn make the supply chain resilient. For the purpose of statistical support to validation of above-mentioned hypotheses the dataset prepared was based on the feedback given by the sampled 20 SC professionals of the selected construction companied (Table 1).

Overview of the Experts

As recommended by Gottlieb et al., 2019, it was under consideration that all the sampled SC professional should have a good experience which managing the different kinds of disruptions. Distribution of the experience of the selected SC Professionals of the sampled construction companies is presented below.

Table 2: Distribution of Experience of Selected SC Professionals

S.No	Construction Companies	Positions	Experience (Years)
1	L&T Construction	SCLM	Less than 10 Years
		SCUM	Less than 10 Years
2	Gammon Engineers and Contractors Pvt. Ltd.	SCLM	Less than 9 Years
		SCUM	Less than 8 Years
3	JMC Projects India Ltd.	SCLM	Less than 11 Years
		SCUM	Less than 7 Years
4	Afcons Infrastructure Ltd.	SCLM	Less than 9 Years
		SCUM	Less than 8 Years
5	Hindustan Construction Company	SCLM	Less than 6 Years
		BPM	Less than 8 Years
6	Tata Projects	SCUM	Less than 12 Years
		BPM	Less than 10 Years
7	Shapoorji Palonji Co. Ltd.	SCUM	Less than 9 Years
		SCLM	Less than 9 Years
8	S.P. Singhla	BPM	Less than 8 Years
		SCLM	Less than 9 Years
9	KEC international Ltd.	SCUM	Less than 11 Years
		SCLM	Less than 8 Years
10	Patel Engineering	BPM	Less than 6 Years
		SCUM	Less than 7 Years

Source: Primary Data (Supply Chain and Logistics Manager – SCLM, Supply Chain and Unit Manager - SCUM, Business Process Manager - BPM)

Industry 4.0 Integration in Supply Chain of the Company

From the feedbacks which were measured on five points scale (1 = Not at All Integrated, 2 = Not Integrated, 3 = Somehow Integrated, 4 = Integrated and 5 = Completely Integrated) given by the experts about the integration of Industry 4.0 tools and technologies in their companies, it was observed that most of the companies to be competitive and to draw the benefits of the intelligent technologies have integrated few feasible technologies in their SC processes. From Table 3, it could interpret that Industry 4.0 Tools and Technologies were broadly classified into three categories namely intelligent technologies, IoT enabled technologies and Cloud enabled technologies.

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Under each category of technologies few specific technologies were considered for the present research work.

Table 3: SC Professionals' Opinion for Industry 4.0 Integration in Companies

	Companies									
Intelligent Technologies	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
a. Big Data Processing	**AI**		**AI**	**AI**	**AI**	NI				
b. Advanced Robotics	NI	NI	NI	**AI**	NI	**AI**	NI	**AI**	**AI**	NI
c. Industrial Connectivity Services		**AI**	**AI**		**AI**		**AI**			
d. Last-generation Sensors		**AI**	NI	**AI**		NI		**AI**		NI
e. M2M and M2H		NI	**AI**	**AI**	NI		NI	**AI**		**AI**
IoT Enabled Technologies	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
a. IoT			**AI**	**AI**		**AI**		**AI**		**AI**
b. Wireless production	NI	NI	NI		**AI**		NI		NI	**AI**
c. BDA		**AI**		**AI**		**AI**				
d. Cloud computing		**AI**			NI		NI		**AI**	**AI**
Cloud Enabled Technologies	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
a. Cloud Computing		**AI**	**AI**			**AI**	**AI**		NI	
b. Visualization Method		**AI**	NI		**AI**		NI	NI		**AI**
c. Service Oriented Technologies	NI	**AI**		NI			NI	**AI**	**AI**	

Source: Primary Data (Ranking: 1-2 = Not Integrated (NI), 3 = Averagely Integrated (AI), 4-5 = Greatly Integrated (GI))

Table 3 helps to know that among all the listed intelligent technologies, IoT enabled technologies and Cloud enabled technologies, according to the opinion of SC professionals Big Data Processing, Industrial Connectivity Services, Last-generation Sensors, IoT, BDA, Cloud computing and Service Oriented Technologies are found more integrated with their construction companies SC.

Industry 4.0 Usefulness in Supply Chain of the Company

Supply Chain professional were also asked about the usability of different listed Industry 4.0 technologies in their respective construction companies and their roles in managing several risks associated with uncertainties and disordering. Usability of Industry 4.0 Technologies was assessed on 3 Points Scale (1 = Not at all Useful, 2 = Intermediately Useful, 3 = Highly Useful) and role of technologies in managing the risks associated with uncertainties and disruptions was also measured on 3 Points Scale (1 = No Role in Managing Risks, 2 = Intermediate Role in Managing Risks, 3 = Good Role in Managing Risks). Selected SC professionals' opinion for the usability or usefulness was carrying higher ratings for Industry 4.0 technologies namely Intelligent Technologies, IoT Enabled Technologies and Cloud Enabled Technologies (Table 4). This confirms that SC professionals' respective companies are aware with the usefulness of the Industry 4.0 tools and technologies followed with its benefits to make the SC more resilient through greater visibility and flexibility.

Table 4: SC Professionals' Opinion for Industry 4.0 Usefulness in Companies

Industry 4.0 Technologies	**Companies**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Intelligent Technologies	2	2	2	3	1	2	2	3	3	2
IoT Enabled Technologies	2	2	3	1	3	3	2	1	2	2
Cloud Enabled Technologies	2	1	2	3	1	3	2	2	2	3

Source: Primary Data (Ranking: 1 = Not at all Useful, 2 = Intermediately Useful, 3 = Highly Useful)

From the SC professionals' opinion for Industry 4.0 usefulness in their respective construction companies, most of the industry 4.0 tools and technologies usefulness were considered as intermediately useful, it is because still companies have not implemented various tools and technologies in their companies due to several feasibility issues such as technical feasibility, operational feasibility, financial feasibility etc. It was also noticed that few technologies are not at all using some technologies in their respective companies.

Table 5: SC Professionals' Opinion for Industry 4.0 Role in Managing Risks associated with Disruption in Companies

Industry 4.0 Technologies	**Companies**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Intelligent Technologies	2	2	2	3	2	2	2	3	3	2
IoT Enabled Technologies	3	1	2	3	1	2	2	1	2	2
Cloud Enabled Technologies	2	2	2	1	1	3	2	2	2	2

Source: Primary Data (Ranking: 1 = No Role in Managing Risks, 2 = Intermediate Role in Managing Risks, 3 = Good Role in Managing Risks)

From the SC professionals' opinion for Industry 4.0 Role in Managing Risks associated with Disruption in their respective construction companies, role of industry 4.0 tools and technologies in managing the risk associated with disruption were considered to be as intermediately useful. It is because companies observe different kind of risks namely financial, administrative, organizational, ecological, technological, legal/ political risks and role of Industry 4.0 tools and technologies in managing the risks is yet not assessed and ensured by the organizations. It is also due to incomplete implementation or ongoing process of implementation of Industry 4.0 tools and technologies. It was also noticed that few technologies' role in managing the risks associated with disruptions in respective companies of SC professionals was not playing any role in managing risks.

Table 6: Correlation between SC Professionals' Opinion for Industry 4.0 Usefulness and Role in Managing Risks associated with Disruption in Companies

Correlations			
		I4.0_Usefulness	I4.0_Risk_Disp
I4.0_Usefulness	Pearson Correlation	1	.763*
	Sig. (2-tailed)	-	.010
	N	20	20
I4.0_Risk_Disp	Pearson Correlation	.763*	1
	Sig. (2-tailed)	.010	-
	N	20	20
* Correlation is significant at the 0.05 level (2-tailed).			

Source: Primary Data

Technologies' role in managing the risk driven through disruptions is imperative, such as Big Data helps in managing the risk associated with the information quality in SC (Zhao et al., 2017), Block Chain facilitates risks associated with the inter and intra organizational activities (Kouhizadeh & Sarkis, 2018), Industry 4.0 advancement helps in managing the risks associated with technological advancements (Panetto et al., 2019), Cloud computing helps in reducing the cost associated with software, technology integration, storage etc., and manage the risk associated with adaptability of system with technological advancements (Sundarakani et al., 2019).

The results shown in Table 4 and 5 it could interpret that in the construction companies (Companies 2, 4, 5 and 8) where the usefulness of Industry 4.0 tools and technologies is observed with compromised or moderate level, the extent of managing the risk due to disruption in the respective organizations is also found compromised or intermediate. So, it could conclude that advanced Industry 4.0 tools and technologies are helpful in managing the risk caused by disruptions.

Higher would be the rate or extent of managing the risks will lead into resilient supply chain through making the supply chain for visible and flexible. From the Pearson correlation statistics (0.763*, .010 <.05) presented in the Table 6, the strong and significant strength of the association between the SC Professionals Opinion for Industry 4.0 Usefulness and Role in Managing Risks associated with Disruption in their respective construction Companies it could statistically confirmed that Industry 4.0 tools and technologies usefulness or usability in the construction companies is directly related with their capacity or observability of managing the risk caused by disruptions.

So, in total it could conclude that digital technologies enabling under Industry 4.0 in the construction companies is beneficial for the SC and make it more resilient through systems or processes flexibility and visibility.

Industry 4.0 Role in Supply Chain Visibility and Flexibility of Company

Industry 4.0 tools and technologies integration in the different processes of the business ensures visibility and flexibility in all the dimension of the business activities through smart designs, smart machines, smart monitoring, smart control, smart scheduling and smart execution means.

The same is noticed in the literature that digital technologies helps in making system more visible and flexible through different checks which confirms the authenticity of the facts recorded and executed through the system and lead into managing the different risk factors. Hence, to know the SC professionals' opinion for the effect of industry 4.0 tools and technologies on visibility and flexibility of the supply chain followed with the managing the associated risks questions was administered in the questionnaire.

On the basis of responses of sampled Supply Chain professionals given for role of Industry 4.0 tools and technologies in SC visibility and flexibility and managing the risk factors is illustrated below (Table 7). SC professionals were asked to give their rating for their opinion in between 0 to 10.

Table 7: SC Professionals' Opinion for Industry 4.0 Role in SC Visibility and Flexibility and Risk Management

Industry 4.0 Technologies	Visibility	Flexibility	Risk Management
Intelligent Technologies	8	7	7
IoT Enabled Technologies	6	7	6
Cloud Enabled Technologies	8	6	6

Source: Primary Data (Ranking: 0 = No Effect, 10 = High Effect)

From Table 7, it is clearly identified that role of intelligent technologies, IoT Enabled Technologies and Cloud Enabled Technologies in making the SC visible and flexible is imperatively identified by the SC professionals. For all the technologies greater than the moderate level of effect of Industry 4.0 tools and technologies on SC Visibility and Flexibility in selected construction companies was noticed. It was also noticed that SC professionals are also agreeing for above moderate level of effect of different Industry 4.0 tools and technologies in managing the risks through ensuring greater visibility and flexibility of different systems and processes of SC.

Table 8: Correlation between SC Professionals' Opinion for Industry 4.0 Role in SC Visibility and Flexibility and Risk Management

Correlations		
		Risk_Mgt
Visibility	Pearson Correlation	.480*
	Sig. (2-tailed)	.032
Flexibility	Pearson Correlation	.538*
	Sig. (2-tailed)	.021

Source: Primary Data

From Table 8, it is clearly identified that visibility derived from application and integration of Industry 4.0 tools and technologies is SC is directly and significantly (0.480, 0.032 <

0.05) associated with managing the risks associated with SC. For flexibility resulted from the Industry 4.0 risks associated with the SC can also significantly (0.538, 0.21 < 0.05) managed. Risk factors associated with the Supply chain can moderately (0.480) managed through visibility and above moderately (0.538) through flexibility. So, alternate hypothesis Ha1: Risk factors associated with the Supply chain can be managed through visibility and flexibility is accepted. Smart designs, smart machines, smart monitoring, smart control, smart scheduling and smart execution enabled through industry 4.0 tools and technologies enable the capacity of managing the risk factors of SC through visibility and flexibility.

Industry 4.0 Tools and Technologies' Role in Supply Chain Resilience

Industry 4.0 tools and technologies through smart designs, machines, monitoring, control, scheduling and execution helps in improving the visibility and flexibility of SC, in continuation the following advantage of implementing Industry 4.0 is related with managing the associated risks of SC. It is also noticed through literature that Industry 4.0 tools and technologies leads in more resilient SC through managing the disruptions. Procurement Operations, Forecasting and Demand Planning, Order Management, Delivery Execution and Supply Chain Data are the major aspect of SC resilience are achieved through Industry 4.0. Hence, to determine SC professionals' opinion for aforementioned aspects of supply chain resilience geared up by industry 4.0 tools and technologies was recorded through questionnaire. Recorded feedbacks of Supply Chain professionals are illustrated below in Table 9. SC professionals were asked to give their rating for factors of SC resilience enriched through the integration of industry 4.0 in between 0 to 10.

Table 9: SC Professionals' Opinion for Industry 4.0 effect on SC Resilience Factors

Factors of SC Resilience	Companies										Avg.
	1	2	3	4	5	6	7	8	9	10	
Procurement Operations	3	4	6	8	3	8	4	6	10	8	6
Forecasting & Demand Planning	8	3	6	8	6	9	3	10	4	8	6.5
Order Management	9	3	7	7	3	8	8	5	8	10	6.8
Delivery Execution	6	4	9	7	3	8	5	6	10	3	6.1
Supply Chain Data	3	5	6	10	7	3	10	10	4	10	6.8
Monitoring	3	5	7	3	3	7	7	6	5	10	5.6
Reliability & Transparency	9	10	3	3	9	10	9	9	8	4	7.4
Avg. Score	5.9	4.9	6.3	6.6	4.9	7.7	6.6	7.4	7	7.8	6.5

Source: Primary Data (Ranking: 0 = No Effect, 10 = High Effect)

From Table 9, it is clearly identified that average scores of each supply chain resilience factor is above the moderate level which confirms that Industry 4.0 tools and technologies have significantly geared up them. Further, it is also identified that except for Industry 2 and 5, for remaining Industries average score of effect of Industry 4.0 tools and technologies is above moderate level which

also confirms that SC professional opinion for the Industry 4.0 driven SC resilience is positive. Statistical determination of significance of difference in the SC professionals' opinion for the effect of Industry 4.0 tools and technologies on different factors of SC resilience was performed by ANOVA (Table 10).

Table 10: Significance of Difference in SC Professionals' Opinion for Industry 4.0 effect on SC Resilience Factors

ANOVA						
Source of Variation	**SS**	**df**		**F**	**P-value**	**F crit**
Between Groups	131.8	19	6.936 84210	1.156 1404	0.3240 7485	1.7625 468
Within Groups	360	60	6			
Total	491.8	79				

Source: Primary Data

From Table 10, it is clearly identified that SC professionals of different companies have approximately same opinion for the effect of Industry 4.0 on the SC resilience factors. Insignificant difference in different companies' SC professionals' opinion is proven through the P-Value 0.32 which is greater than 0.05, and confirms that Industry 4.0 tools and technologies drive SC resilience factors positively. This insignificance of difference in the opinion of the sampled construction companies' SC professionals for the effect of Industry 4.0 on the SC resilience is observed because integration of Industry 4.0 tools and technologies had offered multi-dimensional growth to the sector and somehow it can't be neglected as it was the integral part of industrial revolution (Piccarozzi, Aquilani & Gatti, 2018; Salam, 2019).

Table 11: Correlation between SC Professionals' Opinion for Managing Disruptions by Industry 4.0 and SC Resilience Factors

Correlations		
		Disr_Mgt_I4.0
Procurement Operations	Pearson Correlation	.619*
	Sig. (2-tailed)	.018
Forecasting & Demand Planning	Pearson Correlation	.529*
	Sig. (2-tailed)	.036
Order Management	Pearson Correlation	.603*
	Sig. (2-tailed)	.019
Delivery Execution	Pearson Correlation	.661*
	Sig. (2-tailed)	.009
Supply Chain Data	Pearson Correlation	.542*
	Sig. (2-tailed)	.031
Monitoring	Pearson Correlation	.636*
	Sig. (2-tailed)	.014
Reliability & Transparency	Pearson Correlation	.559*
	Sig. (2-tailed)	.027

Source: Primary Data

Statistical determination of relative association between the SC Professionals' Opinion for Managing Disruptions by Industry 4.0 and SC Resilience Factors is performed through Pearson Correlation test. Test statistics presented in Table 11 revealed that all the factors presenting the SC resilience namely Procurement Operations (0.619*, 0.018), Forecasting & Demand Planning (0.529*, 0.036), Order Management (0.603*, 0.019), Delivery Execution (0.661*, 0.009), Supply Chain Data (0.542*, 0.031), Monitoring (0.636*, 0.014) and Reliability & Transparency (0.559*, 0.027) are significantly associated with the managing disruptions through Industry 4.0 tools and technologies. The relative association for all the SC resilience factors with Industry 4.0 tools and technologies is greater than average, which confirms that SC professional of the sampled construction companies are agreeing upon the imperative effect of the SC resilience and Industry 4.0 tools and technologies are quite effective if managing the SC disruptions. So, alternate hypothesis Ha2: Managing disruptions through Industry 4.0 tools and technologies leads in more robust SC is accepted.

VI. CONCLUSIVE REMARKS AND FUTURE RECOMMENDATIONS

Based on the empirical approach followed to measure the anti-disruptive effect of industry 4.0 on SCM of selected Indian construction companies it is noticed that visibility and flexibility of supply chain plays imperative role in managing the risks at different dimensions of the systems identified due to disruptions leads into supply chain resilience. It was identified that most of the construction companies are at the intermediate level of implementation of Industry 4.0 tools and technologies. Integration of Big Data Processing, Industrial Connectivity Services, Last-generation Sensors, IoT, BDA, Cloud computing and Service Oriented Technologies are identified with greater level of acceptance among different Industry 4.0 tools and technologies. The intermediate level of application or integration I4.0 tools and technologies in selected construction companies is identified due to several feasibility issues such as technical feasibility, operational feasibility, financial feasibility. Due to the intermediate level of integration of technologies managing the risk associated with disruption was also noticed at intermediate level because companies observe different kind of risks namely financial, administrative, organizational, ecological, technological, legal/ political risks and role of Industry 4.0 tools and technologies in managing the risks is yet not assessed and ensured by the organizations. It was statistically assessed and concluded that Industry 4.0 tools and technologies usefulness or usability in the construction companies is directly related with their capacity or observability of managing the risk caused by disruptions. As recorded from the opinion of SC professionals, Industry 4.0 enabled digital technologies are beneficiary for making the SC more resilient through systems or processes flexibility and visibility. Risk factors associated with the Supply chain can be managed through

visibility and flexibility, as the Industry 4.0 tools and technologies offers Smart designs, smart machines, smart monitoring, smart control, smart scheduling and smart execution to the system. The feedbacks of the SC professionals for the effect of Industry 4.0 tools and technologies on different factors of SC resilience was also above the moderate level which confirms that digital technologies make the SC more resilient through offering the advancements in procurement operations, forecasting & demand planning, order management, delivery execution, supply chain data administration, monitoring, reliability & transparency. Imperative effect of the SC resilience and Industry 4.0 tools and technologies is found in managing the different risks associated with SC disruptions and Managing disruptions through Industry 4.0 tools and technologies leads in more robust SC is also observed in vice versa relationship.

Intelligent Technologies, IoT Enabled Technologies, and Cloud Enabled Technologies of Industry 4.0 helps in improving the visibility and flexibility of the SC and also offers the real-time monitoring of different integrated processes simultaneously. Improved visibility, monitoring and flexibility of the SC system helps to predict the disruptions timely and drive different practical approach to manage the risk associated with disruptions.

In order to make the system less vulnerable to several feasibilities which can lead into failure of the technology implementation, it is recommended that different cause and effect, benefit and feasibility analysis should be performed timely. Lesser would be the possibilities identifying the negative effects of the technologies of the existing system, greater would be the rate of successful implementation. In general technologies such as Big Data Processing, Advanced Robotics, Industrial Connectivity Services, Last- generation Sensors, M2M and M2H, IoT, Wireless production, BDA, Cloud computing, Visualization Method, Service Oriented Technologies helps in improving the visibility, flexibility, real-time monitoring, agility of the SC and leads into more resilient SC and ensures the momentum of the business with greater predictability and minimum risk due to disruptions.

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