Enablers of Industry 4.0 in Logistics

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ABSTRACT

Industry 4.0 has impacted every aspect of supply chain and Logistics. In this paper we plan to find out technologies of Industry 4.0 which significantly drive and enable changes in Logistics. Initially the Literature review aims at establishing the variables that act as enablers for implementing Industry 4.0 components in Logistics area of Supply chain. Secondly, the study uses statistical technique of EFA(Exploratory Factor Analysis) to resolve the underlying factors and group enablers into factors. It was observed that four 17 variables group into 4 factors namely Intelligent Logistics, Intrumented Logistics, Core Resources and Business Logistics Sustainability.

Article Received: 10 August 2020, Revised: 25 October 2020, Accepted: 18 November 2020

Introduction

One of the key differentiator of SCM activities is Logistics. Logistics sector is building block of economical ties between countries and making the world Global village. Logistics and freight Industry is expected to be become worth USD 125 Bn in two years. Government is giving push for digitalisation of Logistics using the most advanced technologies.Here comes Industry 4.0 which has gamut of technologies and policies under it which can revolutionise Logistics.

One of the most disruptive topics for discussion in common to elite circles is Industry 4.0.Industry 4.0 resources and technologies are integrated in each function of supply chain for seamless flow of data, information and knowledge transforming local supply chain to global supply chain. This has made supply chain more competitive.Forward supply chain means producing and transferring of goods from through suppliers, manufacturers, distributors to consumers. But with fourth Industrial revolution the Reverse Supply Chain is Integrated through digitization, automation of processes.

The smooth functioning of Forward and Reverse Supply chain is achieved through

Integration of Industry 4.0 in Logistics. This paper explores various enablers or drivers for the same.In order to give holistic approach this paper aspires to present the various underlying enablers that drive application and execution of Industry 4.0 components in each part of supply chain from procurement to logistics. We present 17 potential enablers for application and execution of Industry 4.0 in Logistics. This study will help the organizations to comprehensively evaluate technology enablers.

Literature Review

Industry 4.0 influence each domain of supply chain. Logistics is also hugely impacted by Industry 4.0 [Domingo Galindo ,2016].Industry 4.0 technologies has influenced several key elements of Logistics like warehousing, handling, transporting, handling, distribution. There are several definitions of Smart Logistics or Logistics 4.0 but all definitions come to consensus that "technological development and autonomous processes" are its core feature. [Diwan,2016].Logistics 4.0 has started gaining momentum. Examples are FedEx facility which has employed Jefe Robot in its Distribution Centre. It is used in carrying packages across its huge complex.The robot enabled with sensors avoids obstacles on its way.[Alan Taliaferro et al,2018]

The previous studies have explained in detail of various technologies of Industry 4.0 but has not quantified enablers in logistics domain. This paper tries to establish the enablers and its importance in crisp manner. This paper will attempt to clarify which Industry 4.0 technologies used widely and which technologies are used specifically for Logistics.

[Domingo Galindo,2016] focuses on essential technological components like Cyber Physical Systems(CPS),Radio Frequency Identification(RFID),Human Machine Interface(HMI) for Logistics 4.0.It has integrated technology in Supply Chain which helps in efficient material handling, production,Outbound and Inbound Logistics movement. The embedding of sensors, RFID makes tracking convenient and increases transparency in supply chain.

Industry 4.0 proposes that all elements of supply chain are pioneers of new development.Logistics 4.0 can be build efficiently by smart warehousing activities like Transport Management system(TMS), Warehouse Management System(WMS), and Intelligent Transport system. [Barreto et al ,2017]. Handling of logistics units, Autonomous logistics operations and transhipment technology can be enabled through Industry 4.0 tools such as , RFID , IOT, smart products, Advanced robotics and big data analytics.[Sishi and Telukdarie, 2017;Sung, 2018].The Intelligent Transport system predicts its possible location and time when it will reach.The data is communicated to Warehouse Management system and hence possible dock is allotted by it.

[Gupta et al,2019]explores Artificial Intelligence, Machine learning and advanced analytics for decision making. Utilization of Artificial Intelligence for predictive maintenance is explored[Tao et al,2018] .Ulilization of Artificial Intelligence in production scheduling and planning is also explored[Gilchrist,2016].[Mussomeli et al,2016] evaluates Industry 4.0 technologies like AGV, Automatization, Predictive routing for transforming and optimizing Logistics.

Industry 4.0 should have greater vision to makes Logistics activities sustainable to exert a positive influence on Environment and Economy. The integration of Industry 4.0 framework in Logistics reduce Infrastructural damage, Environment pollution and mobility obstacles. This may be achieved by smart management of heavy freight vehicles, multimodal transport; via Estimation and monitoring of air pollution levels using sensors and actuators and by reducing fuel consumption levels and by encouraging eco-driving Vehicles consequently reducing greenhouse gas emission.
Enablement of Business Logistics is driven by Industry 4.0 resources like real time Information processing and sharing. Green Supply Chain Measures are being implemented to improve relationship between Industry and Environment. Consumer awareness towards Environment issues has significantly increased demand for sustainable products which can be resued and recycled. It has acted as a enabler for reverse logistics and design of Green Logistics Network.
Industry 4.0 resources have been instrumental in developing smart logistics and made it more adaptable and convenient for users and environment friendly. The logistics are interconnected and data is shared across all platforms using ICT to perform tasks sustainably and efficiently. The support from various departments like government support for financial aid for driving and enabling Industry 4.0 in Logistics sector is explored. The assisstance from Department of Science and Technology for encouraging Innovations that can be transformed to commercial products is also taken into account for enabling Logistics 4.0. The investment on human resources for providing training according to Industry 4.0 standards to upgrade skillsets has also been also emerged as significant enabler of Industry 4.0 in Logistics domain.

Methodology

The methodology used is Exploratory factor analysis which is statistical grouping technique and clusters the data into manageable size. "Exploratory factor analysis (EFA) was chosen as a methodology for researcher as larger pool of items can be analysed to identify an underlying factor structure." [Field ,2013;Mulaik ,2009].

Data Collection

Data is collected from June 2020 to August 2020 using a structured questionnaire. The questionnaire was self developed after determining potential key enablers of Industry 4.0 in Logistics after analysing Literature Review. The instrument was subdivided into two sections. First section consisted of basic details like name and Email ID. The second section comprised perceived enablers of Industry 4.0 in Logistics using 17 questions. On the 5 point likert scale, responses ranged from 1(Stongly disagree) to 5(strongly agree).The survey was floated to Logistics managers in organisations and 180 responses was received

Table 1: List of variables and their codes

Importance of ML(Machine Learning) as Enabler of Industry 4.0 in Logistics?	ML
Importance of AI(Artificial Intelligence) as Enabler of Industry 4.0 in Logistics?	AI
Importance of Advanced Robotics as Enabler of Industry 4.0 in Logistics?	ADRB
Importance of cloud computing as Enabler of Industry 4.0 in Logistics?	CC
Importance of data analytics as Enabler of Industry 4.0 in Logistics?	DA
Importance of AGV(Automated Guided Vehicle) as Enabler of Industry 4.0 in Logistics?	AGVL4
Importance of GPS(Global Positioning System) as Enabler of Industry 4.0 in Logistics?	GPSL4
Importance of GIS(Global Information System) as Enabler of Industry 4.0 in Logistics?	GISL4
Importance of HMI(Human Machine Interface) as Enabler of Industry 4.0?	HMI
Importance of RFID as Enabler of Industry 4.0 in Logistics?	RFID
Importance of Remanufacturing as Enabler of Industry 4.0 in Logistics?	ReMa
Importance of Green Manufacturing Initiatives as Enabler of Industry 4.0 in Logistics?	GrMa
Importance of Sustainable Development as Enabler of Industry 4.0 in Logistics?	SD
How Central Government initiatives like Financial Policies has served as Enabler for Industry 4.0 in Logistics?	FS
Importance of support from Department of science for Innovations as Enabler of Industry 4.0 in Logistics?	IN
Importance of focus on Human Resource Training as Enabler of Industry 4.0 in Logistics?	HR

Table 2: KMO Measure of Sampling Adequacy and Bartlett's Test of Sphericity(SPSS Output)

KMO and Bartlett's Test

Kaiser- Meyer- Olkin Measure of Sampling Adequacy		0.803
Bartlett's Test of Sphericity	Approximate Chi-Square	1153.344
	df	120
	Sig.	0.000

Preliminary Analysis

The preliminary Analysis requires finding correlation between variables and if there is no significant correlation($r<0.3$) that indicates that there is very less relationship among variables. Those variables need to be omitted as it shows weak relationship among items so they will not fall under any cluster.

The Anti-Image correlation matrix is analyzed and it shows all diagonal elements with superscript a value are above 0.5. It represents that sample size is adequate and distinct factors can be produced. The first step in process of EFA is performing KMO and Bartlett's test. The test was performed on the overall dataset of responses given by 180 participants and the number of variables are 17. The thumbrule suggests that there has to be 5 to 10 cases per variable [Comrey & Lee, 1992]. The sample size of 180 resulted in KMO value 0.803 which indicates that sample was enough to conduct factor analysis.

The null hypothesis is tested with help of Bartlett sphericity in order to verify if correlation matrix is identity matrix [Bartlett, 1954]. "The null hypothesis is rejected as the test statistic is found significant($p<0.05$)."It is not an identity matrix which indicates that there is sufficient relationship between variables so that it can be reduced and grouped to components

.

Factor Extraction

There are several methods for Extraction like Principal Component Analysis,Principal Axis factor,Maximum Likelihood. "Principal Components analysis is used to extract maximum variance from the data set with each component thus reducing a large number of variables into smaller number of components."[Tabachnick & Fidell,2007]. "Orthogonal rotation is when the factors are rotated 90° from each other, and it is assumed that the factors are uncorrelated." [De Coster,1998; Rummel,1970] We assume factors are uncorrelated for better interpretation.

The PCA with varimax rotation was performed for extraction of factors.It has extracted 4 possible factors. The 4 factors together explain 63 % of variance. The extraction sum of square loadings display the factors whose eigen values are greater than 1. It displays first factor explain 32 % of variance, second factor explain 12.77 % of variance, third factor explain 10.87 % of variance and fourth factor explain 7.83 % of variance. The unrotated factor structure shows that first factor explains most variance whereas subsequent factors explain less variance.

The rotated factor structure optimizes the factor structure where first factor explains 19.311 % of variance,the second factor explains 16.673% of variance, third factor explains 13.635% of variance and fourth factor explains 13.571 % of variance.

Table 3: Variance explained by each component(SPSS Output)

Component	Present Eigenvalues		
	Total	Percent of Variance Explained	Cumulative Percent of Variance
1	5.146	32.165	32.165
2	2.043	12.770	44.935
3	1.740	10.873	55.808
4	1.181	7.382	63.189
5	.907	5.671	68.860
6	.822	5.138	73.998
7	.697	4.359	78.358
8	.612	3.822	82.180
9	.536	3.353	85.533
10	.449	2.804	88.336
11	.424	2.652	90.988
12	.350	2.190	93.178
13	.347	2.167	95.345
14	.295	1.846	97.191
15	.242	1.511	98.702
16	.208	1.298	100.000

Sum of Squared Loadings (Extraction)		
Total	Variance,%	Cumulative variance,%
5.146	32.165	32.165
2.043	12.770	44.935
1.740	10.873	55.808
1.181	7.382	63.189

Table 4:Extraction Methodology-

Table 5: Variance explained after Rotation

Component	Sum of Squared Loadings(varimax Rotation)		
	Total	Variance ,%	Cumulative variance,%
1	3.090	19.311	19.311
2	2.668	16.673	35.983
3	2.182	13.635	49.618
4	2.171	13.571	63.189
5			
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Principal Component Analysis

Table 6: Communalities of Variables(SPSS)

	Initial	Extraction
ML	1.00	.756
AI	1.00	.688
ADRB	1.00	.585
CC	1.00	.515
DA	1.00	.530
AGVL4	1.00	.475
GPSL4	1.00	.655
GISL4	1.00	.665
HMI	1.00	.590
RFID	1.00	.365
ReMa	1.00	.697
GrMa	1.00	.792
SD	1.00	.700
FS	1.00	.761
IN	1.00	.736
HR	1.00	.601

The communalities are greater than minimum value of 0.4 ranging from 0.475-0.795. The communalities indicate how the item is explained by underlying factor. If the communalities are less than 0.4.It indicates that variable does not load on any factor significantly. That variable can be omitted while performing Factor Analysis.[Child, 2006].

Factor Retention

After extraction of factors the next important step is number of factors that should be retained.One of the criteria is to retain all factors which has eigenvalue greater than 1 (Kaiser, 1960). According to this criteria four factors have Eigenvalues greater than 1 and these are retained.Visual method of Scree plot which consists of factors and eigenvalues can also be analysed [Cattell, 1978].However we have only 180 responses and scree test is reliable only when sample size is atleast 200.Moreover,it is just visual method and hence sometimes it not interpreted clearly.

Factor rotation

Component Matrix Component Matrix after VARIMAX Rotation

	Component			
	1	2	3	4
SD	.732			
ML	.627	-.587		
ADRB	.611	-.459		
IN	.608		-.461	
GrMa	.603			-.516
GPSL4	.590		.473	
AI	.589	-.574		
ReMa	.558			-.496
FS	.552		-.447	.436
CC	.547	-.440		
AGVL4	.523			
RFID	.500			
HR	.482			.417
DA	.498	-.508		
GISL4	.492		.561	
HMI	.503		.527	

Table 7: Extraction Methodology-PCA (Principal Component Analysis)4 Components Extracted

	Component			
	1	2	3	4
ML	.840			
AI	.809			
ADRB	.729			
DA	.703			
CC	.678			
GISL4		.803		
GPSL4		.775		
HMI		.756		
AGVL4		.590		
RFID		.536		
FS			.845	
IN			.797	
HR			.748	
GrMa				.855
ReMa				.803
SD				.679

Table 8: Extraction Methodology-PCA Rotation Method: Orthogonal rotation(VARIMAX)

The final factor structure after rotation helped in interpreting the results better

Factor 1- Five variables ML,AI,ADRB,DA,CC loaded onto component 1 with loadings ranging from 0.638-0.840.

Factor 2- Five variables GISL4,GPSL4,AGVL4,RFID.HMI loaded onto component 2 with loadings ranging from 0.536-0.803.

Factor 3-Three variables FS,IN,HR loaded onto component 3 with loadings ranging from 0.748-0.845.

Factor 4- Three variables GrMa,ReMa and SD loaded onto component 4 with loadings ranging from 0.679-0.855.

There is no crossloading in after performing Varimax rotation.

Reliability Analysis

Reliability Analysis was performed after EFA to check reliability of factors.The strong chronbach alpha for all the factors reflect that all factors are reliable and no variable under each factor has to be deleted. It also shows that variables under each factors all strongly correlated.The Cronbach alpha value for component 1 is 0.832.The cronbach value for component 2 is 0.772 .The Cronbach value for component 3 is 0.781.The cronbach value for component 4 is 0.811 .

Reliability Analysis

Cronbach Alpha	Number of Items
.832	5

Table 8: Reliabilty statistic for Component 1

Cronbach Alpha	Number of Items
.772	5

Table 9: Reliability Statistic for component 2

Key results

1.The Machine learning(ML),Artificial Intelligence(AI),Advanced robotics, Data Analytics and cloud computing has large positive loadings on factor one. These items combine together and has served as enabler for Logistics being smarter. Hence this factor is labelled as Intelligent Logistics.

2.The GPSL4(Global Positioning System),GISL4(Geographic Information System), HMI(Human Machine Interface),AGVL4(Automated Guided Vehicle),RFID(Radio frequency Identification) has large positive loadings on factor 2.These items cluster and together indicate Integration of sensors, probes ,process controllers, data loggers to enhance visibility across supply chain and makes tracking easier. Hence the factor is labelled as instrumented Logistics as it serves as key enabler of Industry 4.0 components in Logistics.

3.The FS(Financial support),HR(Human Resource),In(Innovation) has large positive loadings on factor 3.These item cluster and suggests the strategic importance of core Industry 4.0 resources like financial aid given by central government, encouragement of innovation by Department of Science and commerce and focus on Human Resources to upskill them in accordance with Industry 4.0.This factor is labelled as Core Resources.

4.The GrMa(Green Manufacturing),ReMa(Remanufacturing) and SD(Sustainable Development) has large positive loadings on factor 4.This cluster indicates how organization's sustainable development goals has acted as driver for Industry 4.0 in logistics by providing digitalization of forward and reverse supply chain. Reverse Logistics enhance dynamic manufacturing capabilities and contribute in increased introduction of Green Manufacturing and Remanufacturing products in market. This factor is labelled as Business Logistics Sustainability.

Limitations

The limitations in this study was that only 17 enablers were studied. The Industry 4.0 encompasses many technologies and policies, practices according to Industry standard. Those variables should be studied and analysed if they act as enabler of Industry 4.0 in Logistics.

It should be further examined if by adding extra variables the EFA model explains more variance and more factors emerge.

The second limitation was that sample size was only 180 respondents from Logistics domain.

The sample size should be increased as well as there should be more diversity while including responses. Experts from Industry 4.0 should also be considered. The geographic boundaries should also be increased as now only Logistics managers from India are considered as respondents.

Conclusion

The study done in this paper has implications that all the technologies taken into consideration which represent Industry 4.0 is useful for implementing Logistics 4.0. This study will help managers and policy makers to gauge technologies in consolidated manner. A framework is proposed demonstrating 17 enablers of Industry 4.0 in Logistics.It will help managers to judge which cluster of technologies they can implement to achieve operational Excellence in Logistics. Intelligent Logistics, Instrumented Logistics, Core Resources and Business logistics Sustainability will serve as pillars for making logistics smarter. This smart Logistics system will have capability of collection of data in real time by sensors embedded into it. The AI, Machine Learning capabilities will enable route optimization, save fuel and lower pollution levels. The warehouse which is extended arm of Logistics will also be impacted by Logistics 4.0 as high end technologies like WMS and TMS will come to play. The support from government, encouragement for innovations and upskilling of labourers for Logistics 4.0 will create new Employment opportunities. Hence enablers of Industry 4.0 in Logistics will revolutionize supply chain.

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