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(A Double Blind, Peer Reviewed Bi- Annual Journal)

Volume 9 **Number 1** **June 2023**

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Dr. Murali Sambasivan

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Editor-in-Chief

I am thrilled to announce the release of TSM Business Review Volume 9 Issue 1. The issue has eight papers. The first article by Asha highlights the influence of quality of work life and its implications. The second article by Senthilraja shows how integrating Lean Six Sigma with the Internet of Things can help to enhance project deliverables in an automotive setting. The third article by Sumanjeet captures the impact of internet addiction on young Indian students. Quite interestingly, the study also concludes that females are more internet addicted than males. The fourth article by Aruditya analyses the role and importance of festivals in India towards the conservation of nature. It is heartening to note that the Indian festivals are focused on the celebration of mother nature. The fifth article by Jayakrishna highlights the need to include environmental concerns in business operations like supplier selection. This study proposes a green supplier selection model based on the Fuzzy VIKOR method and has tested the approach using a case study. The sixth article by Krishna Kumar highlights the barriers in supply chain digitization and its impact on SDGs. The seventh article by Atour studies the impact of the reform of the Chinese RMB exchange rate formation mechanism on China's trade balance. The eighth article by Vikash tests the applicability of the IFS (Intuitionistic Fuzzy logic) technique in the demand forecasting of immunization vaccines for the rural areas of Jharkhand.

I sincerely hope that the readers will benefit from these papers and continue to support TSM Business Review!!!!!!!!

Associate Editor

It is my pleasure to announce the forthcoming publication of our journal's latest volume, which features a compilation of the most cutting-edge research and developments in our field. As the associate editor of this publication, I am excited to share this valuable resource with our community.

The authors have provided unique insights and findings through their research, which we believe will be of great interest to academics, researchers, professionals, and students alike.

The publication would not have been possible without the contributions of the authors, whose rigorous and innovative work has made this volume possible. We are grateful to them for their hard work and dedication.

We would also like to express our sincere appreciation to the reviewers who have provided invaluable feedback and critique on the submitted manuscripts. Your contributions have been instrumental in maintaining the high standards of our publication and ensuring the quality of the articles published.

Our journal's latest volume is a reflection of our commitment to promoting the advancement of knowledge and providing a platform for the dissemination of ground-breaking research. We believe it will make a valuable contribution to the field and encourage further research in this area.

We hope that the publication will be of interest and use to you and that it will inspire new and exciting research in the years to come. We look forward to your support and continued engagement with our community.

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CONTENTS

Articles….

A Study on Influences of Quality of Work Life and Its Implications

Dr. B. Asha Daisy

Dr. R. Karthi

Abstract

Quality of work life is a procedure by which an organization responds to employee requirements for increasing method to permit them to allocate completely in building the decisions that propose their lives at work. One must have both love and work in one's life to make it healthy. Left are the days when the precedence of employees used to be for physical and material needs. With the rising transfer of the economy towards knowledge economy, the meaning and quality of work life has undergone a drastic change. In this study descriptive design and simple random sampling was used. The primary data was taken with the help of questionnaire for the study.

Keywords: *Employee Requirements, Decisions, Precedence, Economy.*

Introduction

The efficiency and quality of work is affecting by the environment in which people work in a company plays a vital role. The conditions in which workers or other employees work and the contribution are the term now commonly used to indicate. They are able to make in terms of their physical as well as mental abilities and innovative capacity towards improving the performance of a company is called quality of work life. Quality of work life refers to the level of happiness or dissatisfaction one's carrier. Those who enjoy their careers are said to have a high quality of work life, while those who are unhappy are whose needs are otherwise unfilled are said to have low quality of work life.

Objectives

1. To analyze the level of working conditions in the company
2. To understand the satisfaction of workers regarding their working conditions
3. To find out the ways to improve the quality of work life in the company
4. To understand the effects of quality of working life in production

Review of Literature

Saraji and Dargahi (2006) study explained QWL as a complete, department extensive program chosen to progress employee satisfaction, increase workplace learning and helping human resources had enhanced deal with, alter and transition by conducting descriptive and analytical study.

Dr.B.Asha Daisy, Assistant Professor, Department of Management Studies
E.G.S.Pillay Engineering College, Nagapattinam
Dr.R.Karthi, Professor, Department of Management Studies
E.G.S.Pillay Engineering College, Nagapattinam

According to Rethinam (2008) QWL is a multi-dimensional assemble, made up of a numeral of interconnected factors that require cautious thoughtfulness to conceptualize and determine. It is connected with job satisfaction, job involvement, motivation, productivity, health, safety and well-being, job security, competence development and balance between work and non work life.

S. Subhashini, Dr. C. S. RamaniGopal (2013) specifies that productivity should be enhanced when the Quality of work life enhanced.

Dhanesh Uddhav Patil, M S Prabhuswamy (2013) specifies that best practices of QWL in organizations consequences immense impact on the performance of the employees which is also lead employee retention as well as high human resource productivity.

Dr. Devendra S. Verma & Atul Kumar Dohareya (2016) study reveals that the increase in the level of QWL which is in the hands of participative management style.

Research Methodology

The design of the study is descriptive study. It is a research study that describes the characteristics of the variables in a situation. Population is the entire group of people, events or things that the researcher describes to investigate. There are 440 workers in the company the whole workers constitute the total universe of the study. Sample is a subset of population Out of 440 workers 110 workers were selected as sample size of the study. Primary data has been collected directly from the workers using questionnaire especially prepared for that purpose.

Secondary data collected from the annual report, internet and books.

Data analysis and Interpretations

The Table Shows the Gender and Protection Arrangements for Night Shift Staff

Age/ Protection Arrangement	Highly Satisfied	Satisfied	Moderate	Dissatisfied	Highly Dissatisfied	Total
Male	23	45	9	9	5	91
Female	3	6	6	1	3	19
Total	26	51	15	10	8	110

H_0; There is no significant association between age of the respondent and protection arrangement in night shift staff

H_1; There is a significant association between age of the respondent and protection arrangement in night shift staff

O	E	O-E	$(O-E)^2/E$
23	21.50	1.5	0.10
45	42.19	2.81	0.18
9	12.40	-3.4	0.93
9	8.27	0.73	0.06
5	6.61	-1.61	0.39
3	4.49	-1.49	0.49
6	8.80	-2.80	0.89
6	2.59	3.41	3.48
1	1.72	-0.72	0.30
3	1.38	1.62	1.90
Total			8.72

Degree of freedom = (r-1) (c-1)
= (2-1) (5-1)
= 4

95% confidence level
5% level of significance
Table value 5%=9.488
Calculated value=8.72
Table value is greater than the calculated value. Hence H0 is accepted.

Result
Age and protection arrangement for night shift staff is independent.

The Table Shows Age of the Respondents and Physically Exhausted End of the Day at Work

Age /Physically Exhausted	Highly Satisfied	Satisfied	Moderate	Dissatisfied	Highly Dissatisfied	Total
20-25	1	4	6	1	4	16
26-35	2	5	1	2	2	12
36-45	1	2	6	2	3	14
46-50	4	11	8	4	7	34
Above-50	11	8	7	1	7	34
	19	30	28	10	23	110

H_0; There is no significant association between age of the respondent and physically exhausted end of the Day at work

H_1; There is a significant association between age of the respondent and physically exhausted of the day at work

O	E	O-E	$(O-E)^2/E$
1	2.76	-1.76	1.12
4	4.36	-0.36	0.02
6	4.07	1.93	0.91
1	1.45	-0.45	0.13
4	3.34	0.66	0.13
2	2.07	-0.07	2.36
5	3.27	1.73	0.91
4	3.05	-2.05	1.37
2	1.09	0.91	0.75
2	2.50	-0.50	0.1
1	2.41	-1.41	0.82
2	3.81	-1.81	0.85
6	3.56	2.44	1.67
2	1.27	0.73	0.41
3	2.92	0.08	2.19
4	5.87	1.87	0.59
11	9.27	1.73	0.32
8	8.65	-0.65	0.04
4	3.09	0.91	0.26
7	7.10	-0.10	1.40
11	5.87	5.13	4.48
8	9.27	-1.27	0.17
7	8.65	-1.65	0.31
1	3.09	-2.09	1.41
7	7.10	-0.10	1.40
TOTAL			24.12

Degree of freedom = (r-1) (c-1)
= (5-1) (5-1)
= 16

95% confidence level

5% level of significance=0.05

Tabulated value=26.2962

Calculated value=24.12

Table value greater than the calculated value Hence H0 is accepted

Result

The two attribute age and physically exhausted are independent.

Findings

- Most of the respondents are satisfied in the hours of work and work time
- The majority of the respondent is satisfied in the light and ventilation facility
- Most of the respondents are dissatisfied in the basic needs facility
- Most of the respondents are satisfied in the protection arrangements for night shift staff
- Most of the respondents are dissatisfied in the safety work environment
- Majority of the respondents are moderate in the working condition of the company
- Most of the respondent is dissatisfied in the relationship between management and worker
- Most of the respondents are satisfied in the relationship between supervisor and worker

Suggestions

- The company should improve basic need facility because most of the respondents want that basic need facility
- The company should improve the relationship between management and worker
- The company should improve safety work environment in the company because most of the respondents want the good environment in the company
- The company should improve working conditions in the company.

Conclusion

The employee quality of work life aims at providing some facilities good working conditions and good environment as would enable workers employed in industries to perform their work in healthy present able and full pledged working environment. This is always enhancing employee's morale and goodwill about the organization. By having the additional improvement in employee quality of work life in the company gets high profit.

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Digitalisation of Lean Six Sigma Project Management with IoT: Evidence from Automotive Industry

V. Senthilraja

Abstract

In the current digital era, traditional process improvement practices deserve a revamp in alignment with the changing environments. Therefore, purpose of this study is to integrate Lean Six Sigma (LSS), a reputed process improvement practice with the Internet of Things (IoT). The study conceptualizes the amalgamated IoT-LSS framework and test it in a commercial vehicle prototype workshop context for practical value. Also, study reveals how IoT integration can improve the project deliverables in an automotive setting. Our findings indicate that LSS plays a significant role in new product development, via data- and process- analytic lenses that get enhanced with the support of IoT towards creating a process improvement ecosystem in organisations. Subsequently, the case evidence and discussion provide managerial implications and an agenda for future research.

Keywords: *Lean Six Sigma (LSS), Prototype Workshop, Internet of Things, Process Improvement, SDMMAICS, Automobile.*

1 Introduction

The automobile industry is a prominent part of the manufacturing sector and is an indicator of the economic development of any country (Narasimhan, 2009; Bhatia et al., 2020). Due to its high demand for consistently high performance and quality, it is referred to as technology and knowledge-intensive industry (Sreedharan et al., 2019). The automobile industry in India has deep links with many segments of the economy. This industry has a strong multiplier effect and can be a driver of economic growth (Singh, 2017). As per a recent study, the performance of the automobile industry can also be correlated with the health of the economy (Sunder M & Kunnath, 2020). Besides, increasing market competition and customer demands towards price reduction and quality improvement have led many automotive and aerospace industries to embark upon process improvement programs. Literature shows that Continuous Improvement (CI) enables this effect (Lametal, 2015). Over the years, CI has influenced both academicians and practitioners for its applicability and assured cost savings (Nitin et al., 2005; Sunder M et al., 2020). While a few firms have reported several success stories of CI, a few others have looked at CI merely from a project management perspective (Sunder M, 2016). However, with increasing customer demands, there is a compelling need in front of corporate firms to embark on CI journey, and the automobile industry is not an exception. Hence, there is a strong need for automobile firms to focus their efforts on improving time to market metrics, quality, product development, and associated knowledge management for achieving

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competitive advantage (Bacoup et al., 2018). Several CI approaches exist in the literature, such as Total Quality Management (TQM), Six Sigma, Lean, Lean Six Sigma (LSS). Lately, LSS is one of the contemporary CI approaches used extensively in the last decade (Sunder M et al. 2018). Many studies show applications of LSS across manufacturing and services (Furterer, 2016). However, the application of LSS with IoT in the automobile industry has been limited and literature review shows that no studies has examined the application of LSS with IoT in the context of a Prototype workshop. Taking this as a valuable opportunity, the present research focuses on:

RQ: How to digitalize LSS project management with Internet-of-Things (IoT) for commercial vehicle prototype building practices?

The study focuses on integrating IoT with LSS and, based on the demand for commercial vehicle study, tested the IoT-driven LSS project management in a commercial vehicle's prototype workshop. Further, this study provides unique contributions, such as (*i*) integrating IoT and SDMMAICS for field application in a manufacturing setting; (*ii*) overcoming the issues related to proto build using IoT ecosystem; (*iii*) developed the IoT enablers for daily Management for Prototype workshop; (*iv*) introducing process automation and time stamping for proto conversion for job congestion; (*v*) discussed the cost of investment for the IoT ecosystem.

Following the introduction, the remainder of the paper is as follows. In section two highlights the work related to IoT and LSS. Next, section 3 featured the method and followed by a case study in section four. Then, section five reports the discussion of findings followed by implications, and the study concludes with agenda for future research.

2 Literature Review

2.1 LSS & Commercial Vehicle

Since the introduction of lean manufacturing methodologies in the late 1970s, they have been increasingly internalized by most industrial and service companies in various sectors (Sodhi, 2020). Nowadays, continuous improvement programs based on LSS have become a pillar of the most influential and medium-size development strategies (Chiarini and Kumar, 2020). In addition to the visual tools provided by the toolbox, LSS brings advanced statistical tools that help better measure, analyze, and solve the problem at hand (Sunder M et al., 2020; Sunder M & Kunnath, 2020). The literature review conducted by PanayIoTou and Stergiou (2020) shows that LSS is adopted in sectors ranging from healthcare, finance, and higher education to manufacturing industries (e.g., automotive, aerospace, food, electronics, etc.).

In the automotive sector, the application of LSS has been studied both from a manufacturing and a human perspective (Ozcan et al., 2020; Adebanjo et al., 2021). Several authors have considered implementing the LSS methodology from a human resources perspective in the

automotive industry. Azadeh et al. (2017) evaluate the consequences of LSS deployment on job satisfaction, stress, and security in an automotive factory. Their study shows that LSS implementation has a positive impact on the overall working condition and thus on job satisfaction. Their findings are in line with several other studies that point out the positive effects of LSS implementation on employees' morale and delight with their job (Lang Cheng, 2012; Schön et al., 2010)

Ben Rubben et al. (2017) discuss the implementation of LSS in the production of cars' components in terms of car manufacturing. Based on the Define-Measure-Act-Improve-Control (DMAIC) methodology, the authors develop a framework that integrates LSS and environmental impact assessment tools to reduce overall defects and the firm's environmental impact. Noori and Latifi (2018) deploy the LSS methodology and change management tools to reduce defects in the griding Process relative to engine manufacturing. Kumar et al. (2006) also investigate the role of LSS in reducing blemishes, taking automobile accessories manufacturing as a study context. The authors develop a framework that integrates lean tools such as the 5S system and total productive maintenance into the DMAIC methodology to enhance key performance metrics in the die-casting Process. Thomas et al. (2009) evaluate the effectiveness of an integrated LSS approach to reducing the rejection rate in the pilot line. According to the authors, saving about £29,000 can be expected by implementing the LSS methodology.

Despite its historical ties with lean management, the literature has not paid much attention to LSS implementation in the automotive industry (PanayIoTou and Konstantinos, 2020). In addition, available contributions primarily target issues with manufacturing already designed products, omitting the product development phase, especially prototyping. Developing prototypes is an essential validation step towards the development of optimal product designs and production processes (Sunder M and Prashar, 2021). Considering this as a research gap, this paper finds implementing the LSS methodology in a prototype workshop.

2.2 Combining LSS and Industry 4.0

With the rise of a new generation of connected commercial vehicles, the automobile industry has taken a giant leap towards the rapid implementation of high-fidelity hardware supported by smart electronic components (Manimuthu et al., 2021). Such a leap makes the manufacturing process smarter through emerging technologies such as the Internet of Things (IoT) and artificial intelligence. This transformation is referred to today as industry 4.0 (Ejsmont and Gladysz, 2020). The recent technological advancements in ICT, such as cyber-physical systems (CPS) and IoT, combined with reasonable hardware and software solution prices, enabled a rapid transition to smart and connected factories (Almada-labo, 2016). Industry 4.0 represents "*the usage of intelligent products and processes, which enables autonomous data collection and analysis as well as the interaction between products, processes, suppliers, and customers through the internet*" (Buer et al., 2018). According to Roy et al.

(2015), combining Industry 4.0 and lean manufacturing into a *lean automation* concept can improve the performance of factories. Lean automation stands for low complexity automated systems that fit into the lean production environment (Jackson et al., 2011). Research has shown that lean manufacturing principles serve as an ideal foundation for the introduction of industry 4.0 technologies (Dalenogare et al. 2018), as low levels of complexity facilitate automation and digitalization (Kolberg and Zühlke, 2015). Staufen (2016) empirically found that industry 4.0 pioneers share the common characteristic of an already established lean manufacturing system. Khanchanapong et al. (2014) advance that, to maximize manufacturing performance, the introduction of advanced technologies needs to be supported by lean practices. As such, lean management and industry 4.0 do not contradict each other but rather work in synergy to improve firms manufacturing performances (Khanchanapong et al., 2014).

While the concept of combining industry 4.0 and lean management has the potential to improve the manufacturing performance, Buer et al. (2018) note that knowledge on how to integrate the two is still limited. Wagener et al. (2017) and Wang et al. (2019) also came to the same conclusion. Also, Jayaram (2016) discusses the possible integration of LSS with industry 4.0, which requires four main components: connectivity, visualization, optimization, and autonomy. While their work shows the complementarity between LSS and industry 4.0, insights into achieving this integration are limited.

Table 1 Studies on IoT and Lean Practices

Authors	Approach	Area of Application	Technologies used	Type of Industry
Anosike et al. (2021)	Survey	Lean Methods	IoT technologies (RFID, WSN, and Middleware)	Manufacturing Industry
Xing et al. (2021)	Case Study	Lean Construction	Last Planner System (LPS) and IoT	Construction
Beliatis et al. (2021)	Case Study	Lean Digital Shop Floor Management	IIoT & RFID	Manufacturing Industry
Yadav et al. (2021)	Explorative	Lean Six Sigma	IoT	Automation
Idrissi et al. (2021)	Empirical	Intruder Detection System	IoT & Botnet	Cyber Security
Abd et al. (2021)	Empirical	Lean & Decision Support System	Decision Support System	Manufacturing Industry
Lu et al. (2021)	Empirical	Digital Twin-Enabled VSM	IoT & Efficiency Validate Analysis	SMEs
Jiang et al. (2021)	Case Study	Waste Segregation	IoT & Subscription	Waste management
Abed Et al. (2020)	Empirical	DMAIC	IoT & DoE	Manufacturing Industry

Yadav et al. (2020)	Survey	Lean & Emerging Technology	IoT & ICTs	Manufacturing & Service Industry
Dutta et al. (2020)	Survery	Manufacturing Excellence	IoT & Manufacturing	SMME
Rudnick et al. (2020)	Case Study	Lean Service	IoT & PSS	Train Maintenance
Ito et al. (2020)	Empirical	Decision Support System	IoT & Data Analytics	Manufacturing Industry
Roy et al. (2019)	Empirical	Smart Management System (Smgs)	IoT & Big Data	Manufacturing Industry
Zhang et al. (2019)	Theoretical	Lean-Oriented Optimum-State Control Theory	Industrial networking system	Manufacturing Industry
Yin et al. (2018)	Descriptive	Toyota Production System	Industry 4.0	Manufacturing Industry
Arcidiacono & Pieroni (2018)	Empirical	Lean Six Sigma 4.0	Industry 4.0 and QoE	HealthCare
Chang & Yeh (2018)	Case Study	Talent Management	IoT; Big Data & Cloud computing	Human resource management
Yerpude & Singhal (2017)	Empirical	Inventory Management	IoT & Vendor Managed Inventory	Supply Chain Management
Steenkamp et al. (2017)	Explorative	Smart Production System	IoT	Manufacturing Industry
Trstenjak et al. (2017)	Empirical	Process Planning	Industry 4.0	Mass production
Cho et al. (2015)	Theoretical	Self-Directed Learning	IoT	IoT Based Environment

***Legend**: QoE-Quality of Experience; DoE-Design of Experiments; ICT-Information and Communication Technology; PSS-Product Service Systems; RFID-Radio Frequency Identification; IIoT-Industrial Internet of Things; WSN- Wireless Sensor Network; DMAIC-Define, Measure, Analyse, Improve, Control.*

Later, Chiarini and Kumar (2020) explore the integration issue by investigating how industry 4.0 technologies can be integrated within Lean tools and principles. The authors conclude that such integration requires a complete automatic synchronization of the processes and real-time data collection and analysis, made possible by technologies such as IoT. For extant article review (refer to Table 1), this study is the first of its kind that attempts to answer "how" to integrate lean management and industry 4.0 which is supported by various connotations of literature in table 1. This paper further contributes to this research gap by conduction a process improvement base case study including both LSS and IoT as a component of industry 4.0. Further, Jayaraman et al. (2012) highlighted that DMAIC techniques provide a structured

approach to problem-solving with enhanced bottom-line results. Sreeram and Thondiyath (2015) combined using Six Sigma and Lean concepts and found it a helpful structure for process improvements. A composite system provides better visualization of the components, and it illuminates the gaps in continuous improvement. Sunder M et al. (2018) highlighted the drawbacks of applying individual Lean and Six Sigma methods. They emphasized their synergies that come in handy for presenting integrative structures of process improvements in firms. Using PDCA as the basis for these frameworks, three case studies were conducted to evaluate the application of this integrative LSS model. Though several cases affected the application of the hybrid LSS method, from an extant review of the literature, it is found that academic literature concerning process improvement in the Prototype workshop for a commercial vehicle is minimal. This study is conducted by taking this LSS theory testing gap in the context of Prototype workshop as a valuable opportunity. Researchers believe that the investigation would be advantageous to both practitioners and academic communities.

2.3 Need for IoT in Prototype Workshop

Commercial vehicles require more safety and structural modifications when they are deployed and tested in an open environment. From 2000 to 2012, most commercial vehicles in the market were fuel injection types equipped with a maximum of 2-5 embedded components and sensors (Collingwood, 2017). In early 2013, the automobile industry took a giant leap towards rapid implementation of high-fidelity hardware supported by smart electronic elements. Embedded software is used to incubate structural modifications in designing systems provided with internet connectivity and can be able to communicate with the external data world via their inbuilt sensors and actuators (Bagloee et al. 2016). These sensors lead to state transitions from manual-semi-autonomous- completely autonomous commercial vehicles in the energy market. The conventional energy distribution is ruled out with intelligent battery-operated vehicles, and the drivetrain has been modified to adapt numerous electronic elements for the safety and security of data. Since the features are integrated with embedded components, it is easy for them to interact with the external world using internet connectivity. IoT plays a significant role in mapping, navigation, localization, and remote assistance to the vehicle from all corners of the world. From Research and Development (R&D) to Assembly, Polishing and Quality improvement and delivery and mobility assistance are provided by the IoT enabled commercial vehicles (Bansal et al. 2016). Data generated from the installed sensors were handled safely and delivered to the processing centers for system diagnosis and boost the system performances.

Multi-sensor data fusion and sectional cross-feeding of data elements from different sensors in the vehicles helps the manufacturer design, test, and analyze every element of the vehicle. Also, in the detailed exploratory fashion and provide taglines for easy identification of faults at nay design stages. Like domestic transportations such as cars and buses, heavy vehicles like trucks and trams are becoming increasingly deployed with software, connectivity elements and meets communications standards (Rajamaki, 2013). Thus, Vehicles can make real-time

decisions and much more robust and reliable in terms of data generation and processing. Any uncertainty in data generation or exchange may lead to catastrophe (Hevelke and Nida-Rümelin, 2015). Artificial Intelligence (AI), Big Data, and Machine Learning (ML) for data collection, processing, and decision making produce additional support to the manufacturers. In semi-autonomous vehicles, the embedded software tools and intelligent IoT sensors will learn, Process, and adapt to the driving pattern of the drivers and suggest decision-oriented attributes for smooth driving of the vehicle (Renn and Benighaus, 2013). With the advent of telematics and cross-platform communication infrastructures, it is easy to implement LSS models to incubate IoT and AI paradigms for business enhancements, drift in modeling, and industrial marketing (Fountaine et al. 2019). Further, most of the studies in product development used QFD, Lean, thinking for their studies (Sunder M et al., 2020). However, none of the studies tried to use IoT in the prototype workshop setting.

Furthermore, most studies preferred DFSS, DMAIC, and DMADV (Cheng, 2008; Spasojevic 2016). However, a new and more robust LSS project management approach is used in multi-case studies known as SDMMAICS (Krishnan et al., 2021). Therefore, a study has integrated IoT and SDMMAICS for the LSS project in the prototype workshop, taking this as motivation.
From the discussion above, this paper has the following research objective:

- To integrate IoT and LSS to enhance manufacturing performance in prototype workshop?

3 METHODS

The study used the SDMMAICS model for testing the impact of IoT in a prototype workshop for commercial vehicles. Further, studies on IoT and Lean Practices show (refer to table 1) that most of the studies were carried out using the Case study approach. It is also clear that studies from late 2020 onwards focused mainly on IoT for their theoretical and practical applications proving that IoT is the most sorted technology in Industry 4.0. Furthermore, as per the importance of case study in the LSS context. The Select-Define-Measure-Map-Analyse-Improve-Control- Sustain (SDMMAICS) methodology is part of LSS project management and was used in part manufacturing (Sreedharan and Sunder, 2018). Later in Process improvement-based study for reamer manufacturing process (Krishnan et al. 2020) proves the robustness and adaptability of SDMMAICS for the present work. Further, the study used a case study approach to address the research question because:

- Case Studies offers flexibility for applying both the qualitative and quantitative analysis in the context of LSS (Sreedharan and Sunder M, 2018; Sunder M et al., 2020)
- It provides a medium to investigate the complex concept and understand the case aptly (Sunder M et al. 2016)
- The case study is a known method to explain LSS cases from manufacturing Industries (Sokovic et al., 2010; Sreedharan et al. 2018)

4 Case Study

4.1 Background

The case study was conducted in a leading Automobile Manufacturing Company located in the UK, India, UAE producing commercial vehicles like trucks, buses, minivans, cars, and utility vehicles. This case is an original contribution by the authors with no permissions to disclose the details of the study organization and associated dependencies. They have trucks from 02 tonnes (Gross vehicle weight) to 49 tonnes (Gross vehicle weight). Further, the company produces trucks for defense applications and public utilities. So, the company has made 6 million trucks. Presently the company is focusing on developing a truck prototype with an intelligent system. The LSS team (Proto lead; Design engineer; Line Supervisor; Motorman for Welding and Fitting operations) used IoT, and the SDMMAICS approach in the Proto build Process to reduce lead-time and improve the quality of the prototype. This Process will also help in the testing and verifying an IoT setup for the prototype workshop, as shown in figure 1.

4.2 Select

Force field analysis is used in the select phase to choose the preferable project (Sreedharan and Sunder M, 2018). The force field analysis (Refer Table 2) facilitates the LSS team to identify the issues in the project selection. It collects input from the key stakeholders and classifies them as restraining forces and driving forces. Further, the force field considers the various hurdles present in the organization to ensure the right project is chosen. The stakeholders were asked to give their preferences on a scale of five. Out of five, one being the least accepted and five being the most accepted. Based on analysis for force field analysis in table 2, the LSS team found that proto building is the most preferred project.

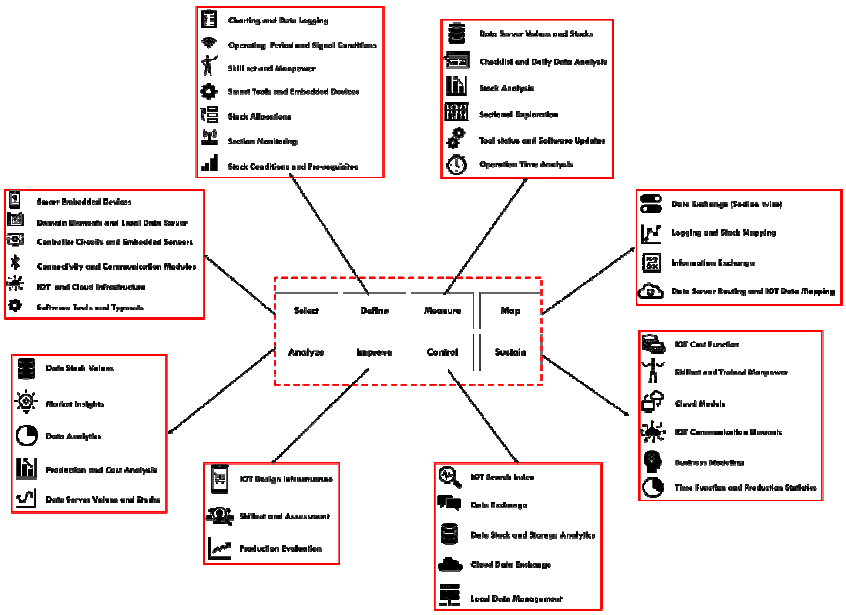


Figure 1 IoT Setup for the Prototype Workshop

Table 1 Force Field Analysis

Driving Force *(Positive)*	*(Force Strength)*											Restraining Force *(Negative)*
	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5	
To achieve better Proto Build												External consultant intervention
Increase Proto conversion												Conversion request
Maintaining Throughput level												Mismatch in Service Level Agreement
Invest in IoT												Design and modeling constraints
Total Score	+12					-10						Total Score

4.3 Define

To conduct a process effectively, project definition is vital. The LSS team has developed the project charter for the prototype workshop (refer to table 3). The project charter highlighted the business cases and its goal with the LSS team members. Here in this Process, the design engineers and testing engineers are the suppliers for the Prototype workshop, and they can raise proto requests as Cluster, in the form of Testing Groups and materials. Besides the proto build activity, the critical information and inputs are required to meet the deliverables, and the input details include Drawings; Engineering Sketches; Torque values, Measurable Parameters. Based on these necessary conditions and inputs. The Proto build process is categorized into three jobs. (1) New proto build; (2) Proto Conversion; (3) Miscellaneous Job.

- ***New Proto build*** is defining as the Process of coining a new product against the design details by the design engineers; this is from the scratch level to the product for validating the design concepts by producing the tangible physical product (Chauhan et al., 2020).
- ***Proto Conversion*** is the Process of changing the significant aggregates in the new proto build vehicle for validation and verification of totals for the final product.
- ***The miscellanies' job*** is the minor work, which consists of changes of systems in the vehicle to validate the vehicle's operations or rework of systems.

Table 3 Project Charter

Product/service impacted	Proto build	**Team Leader**	AAA
Business unit	Prototype workshop	**Phone guide/mentor**	BBB
Champion	BBB	**Company name**	Automaker
Element	**Description**		
Business case	The company is an automotive sector dealing with a commercial vehicle. They aim to produce high-quality components at competitive prices. The company aims to meet the SLA		
Problem statement	For Nov 2016- Mar 2017, there is a 24-day SLA for proto build supported by an external consultant. The aim is to reduce the SLA through process improvement and further complete the proto build using in-house experts for the following metrics: Average Jobs of New proto build; Average Jobs of Proto conversion; Average Jobs of Miscellaneous; The average demand for Jobs per month		
Goal statement	To reduce the time consummation for proto build and develop the process improvement in the Prototype workshop.		
Project scope	Focus on process flow, challenges in SLA, GAP analysis, and Job prioritization		
Team members	Proto lead; Design engineer; Line Supervisor; Motorman for Welding and Fitting operations		
Schedule	**Date of Completion**	**Goal**	
	04/12/20	Select - Define	
	14/12/20	Map - Measure	
	23/12/20	Analyze	
	10/01/21	Improve	
	15/01/21	Control	
	05/02/21	Sustain	

The project charter shows that the design, verification, and validation of the product are instrumental for the Proto build. However, product quality and design issues for analysis and redesign make the process complex. Therefore, the LSS team developed a SIPOC diagram (refer to figure 2) to comprehensively understand the Process (Davidson et al. 2001; Hilton and Sohal, 2012). From the SIPOC, the LSS team found opportunities to reduce the proto build lead-time and to improve the quality of the proto build activities**.**

4.4 Measure

The development of the SIPOC from the define phase enabled us to proceed to the Measure phase of the SDMMAICS framework. In this Measure phase, the researchers have to collect the

data using the check sheets of the proto build process for the three months in different aspects to get the actual variation (Sunder M, 2016). So, the process gap can be identified as the actions to be addressed to improve the productivity and the quality of the Process in the Prototype workshop (Tonnessen et al., 2000; Sreedharan and Raju, 2016). The primary activity is to measure the time for proto completion. As shown in figure 3, the data collection plan for the month category-wise offers the program for the months (Nov 16, Dec 16, and Jan 17) about the proto build jobs category-wise. Based on the information from figure 3. Researchers found that the Service Level Agreement (SLA) could be improvised by making the Process more efficient due to poor process flow leading variation in SLA as in figure 3. Further, researchers found a gap between the proposed and actual Processes, which is tabulated in Table 4.

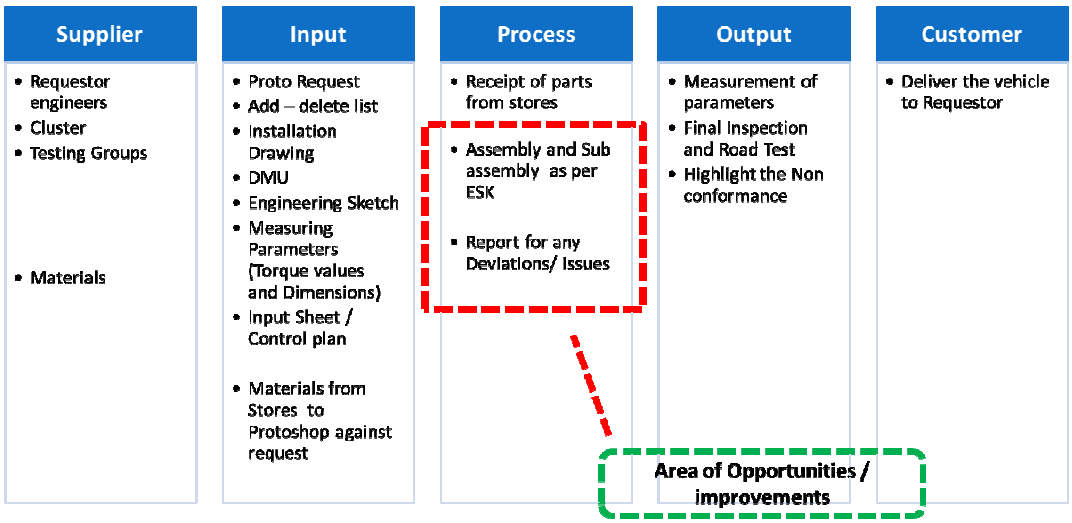


Figure 2 Supplier Input Process Output and Customer (SIPOC)

Table 4 Protobuild Plan Vs. Actual Data

Job Category		Nov-20	Dec-20	Jan-20	Feb-20	Mar-21
New Proto Build	Plan	5	6	4	5	7
	Actual	5	6	4	5	7
	Gap	0	0	0	0	0
Proto Build Conversion	Plan	13	18	12	17	15
	Actual	11	14	10	15	14
	Gap	**2**	**4**	**2**	**2**	**1**
New Proto Build	Plan	36	32	38	29	31
	Actual	27	19	30	27	30
	Gap	**9**	**13**	**8**	**2**	**1**

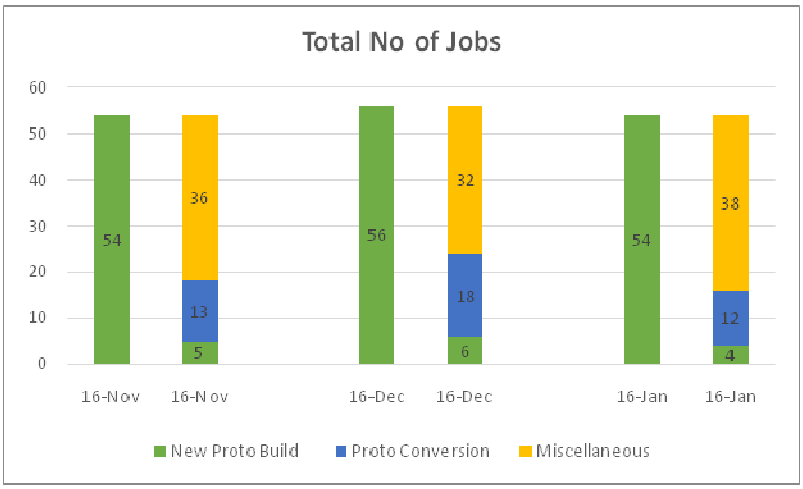


Figure 3 Data Collection – Plan for the Month Category Wise

4.5 Map

The proto head conducts a brainstorming session with his peers to understand the Customer Need Analysis (CNA) in the mapping process. From this, the activities were executed by the proto team in two groups. (1) Job Card (2) System process. In the Job card, the shop workshop executives discuss and monitor the material flow of the job. The job status is updated to the test engineer. In the System process, the test engineer discusses the job progress with a test plan. The test plan is evaluated by the proto head and the proto team. After careful evaluation, the team releases the Problem Notifcation (PN) report and cross verifies with customers' requirements (CNA). The Process continues till the PN is addressed and approved by the proto head and proto team. Once the job card and system process fulfill the CAN, the test engineer prepares the final report and leads to the final product, as depicted in figure 4.

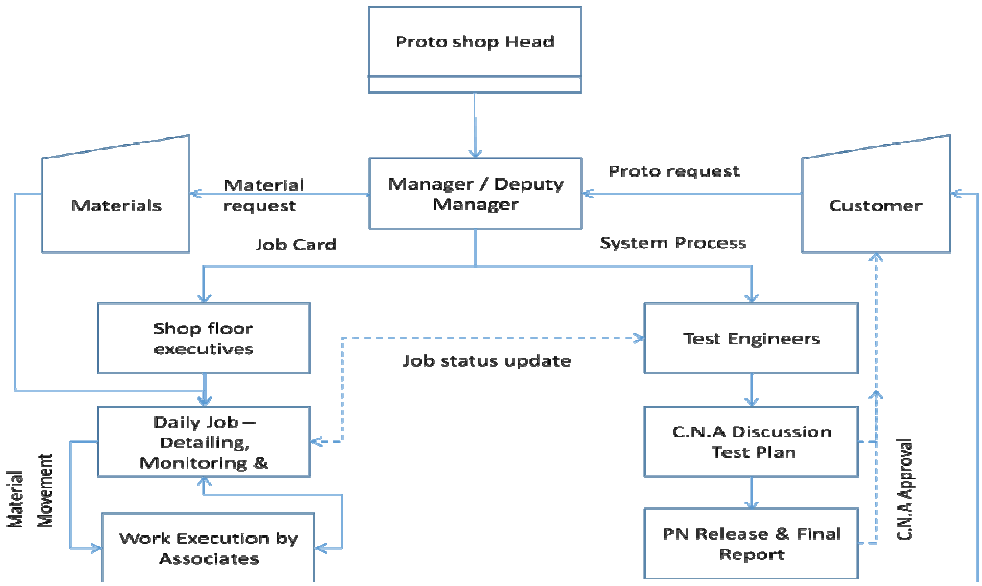
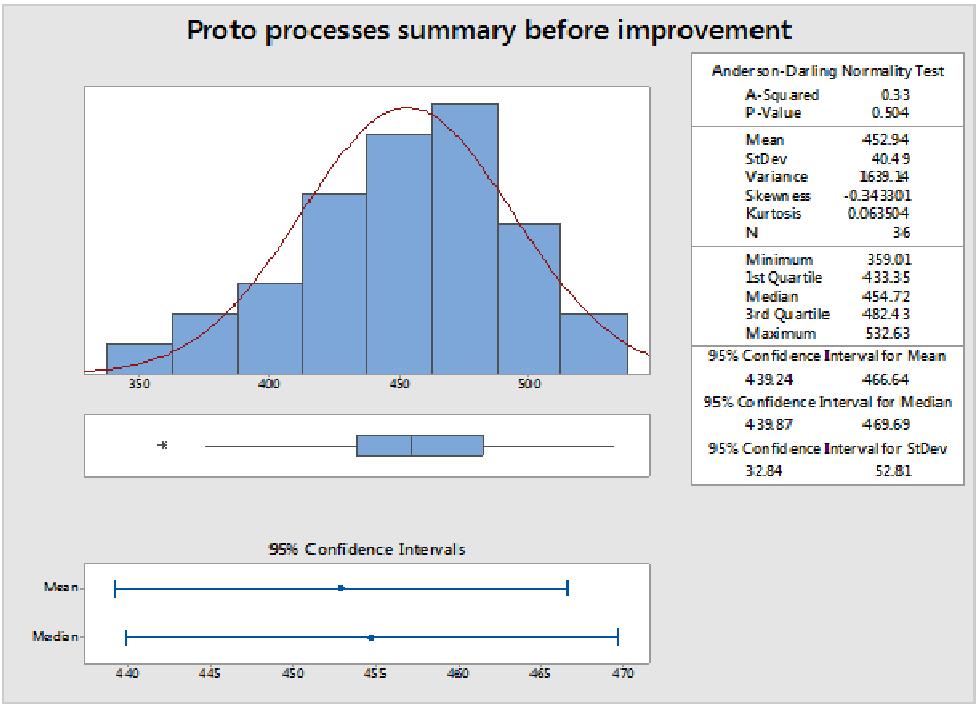


Figure 4 Process Map - Prototype Workshop

In proto build jobs, the plan for each month is collected by the proto team and focuses on the proto build for design verification and validation. Also, the proto team ensures to have no delay in the proto build. However, the proto team's different tasks like proto conservation, new proto build, and miscellaneous are simultaneously carried out. Such activities create a GAP (Planned vs. Actual schedule) in the proto-building Process (Mineraud et al. 2016). ***In proto conversion***, the existing proto build vehicle or the new vehicle from the plant are converted for EDM (Engineering Design modification) to verify and test the EDM changes. The GAP noticed in this category is very minimum.

In contrast, Miscellaneous has more gaps due to the customer request. Besides, to reduce the GAP, the proto employ an external consultant with a fee of 5500 USD per month. Therefore, using a time-motion study, the LSS team recorded the time need to complete the prototype processes such as new prototype building, prototype conversion, and miscellaneous. As it is a time-based metric and on a continuous scale, the stability and normality of the data are checked. The turnaround time (TAT) to complete the prototype processes was 450 minutes with a deviation of 35 mins. Even though the Process shows normality (p= 0.504; 95%) in Anderson – Darling test and the data are plotted in I- Chart to check its stability. The data are within limits (Refer figure 5). However, the deviation of 35 minutes shows high variation in the prototype process with an increase in lead time.



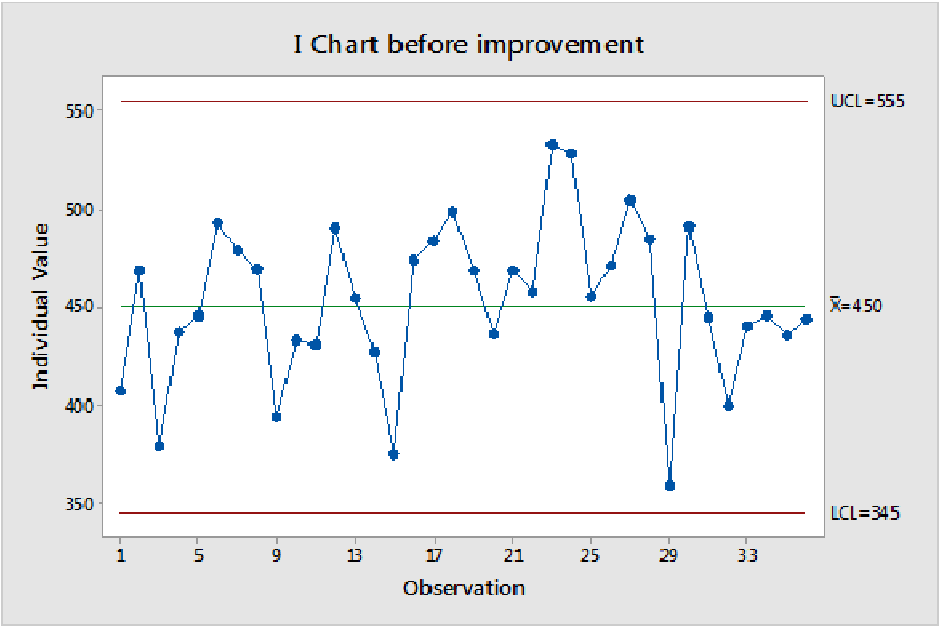


Figure 5 TAT for the Prototype Processes

4.6 Analyse

The LSS team observed the proto building process and analyzed the data from the planned and actual proto build leading to the cause-effect analysis as shown in figure 6. In our case, the GAP between the plan and actual is more in the proto building, and it has to be reduced. Based on the ***Cause-and-Effect Analysis*** some of the issues are:

- Inadequate Prioritization of jobs
- PDCA not followed for routine jobs
- Unwanted movement of materials inside the shop floor
- More Congestion of jobs (miscellaneous / conversion)

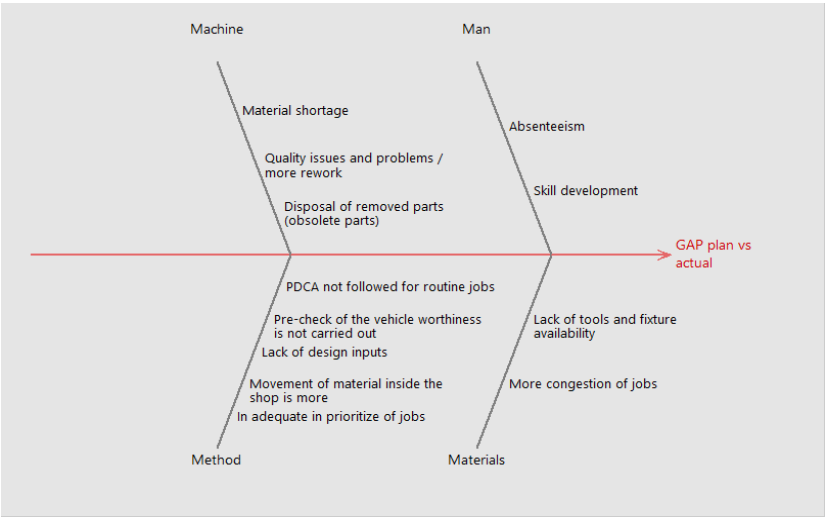


Figure 6 Cause and Effect Analysis

As tabulated in Table 5. the inadequate Prioritization of jobs in the proto build and the categorization will confuse the job detailing. Also, lack of clarity in job criteria and allocation of resources to the minor priority project. Hence, the LSS team suggested Job prioritization in advance, including the priority ranking in the weekly plan, and releasing the weekly program to the shop floor executives to detail the job and get the execution of the jobs from the associates. Further, brainstorming with the associates highlighted the work congestion and quality issues (refer to Table 5), creating the prototype workshop's action plan.

Table 5 Cause and Effect Analysis for the Prototype Workshop

What	How	Who	When
Prioritize of Jobs			
Inadequate in Prioritizing jobs	New Project – Job priority to be used as a tool to avoid the inadequacy in prioritizing	Head Proto shop	Jan 2017
Lack of clarity in jobs criteria	SAW – Simple Additive Weightage method		
No priority fixing in weekly planning	No clear action plan for Prioritization		
PDCA not Followed for Routine Jobs			
PDCA not followed for routine jobs	Implementation of Daily Management and PDCA cycle for regular jobs and daily review of the deliverables are introduced	Manager Proto shop	Jan 2017
Inadequate Daily Management	Format introduced		
Inadequate Review of Routine Process	Daily jobs; Weekly Plan Vs. actual; Monthly Plan Vs. actual		
Unwanted movement of materials in shop floor	Non-Value-adding activities will be removed by using the Value stream mapping for the material flow in the shop floor	Manager Proto shop	Jan 2017

4.7 Improve

In this phase, the LSS team has suggested improvements to implement a feasible solution. It is necessary to reduce the GAP in the proto build and improve the quality of the prototype build. The LSS team observed issues in Congestion of Jobs and Quality issues and rework problems. The LSS team provided the solution to these issues and created responsibility by assigning a process owner as tabulated in Table 6.

Table 6 Issues in the Prototype workshop

Types of Issues	Reason	Solution	Process Owner	When
Congestion of Jobs	More Congestion of jobs (different/ conversion) due to fluctuation in proto request jobs and improper routing of Jobs Vs. Categories (new proto build/proto conversion/ miscellaneous)	Using TRIAGING process reduction of Congestion and developed different routing strategies for resources to deal with (new proto build/ proto conversion/ miscellaneous)	Manager Proto shop	Jan 2021

Quality issues and problems / More Rework	Quality Issues and problems of Supplier parts, Parts are developed by general engineering method not tooled up parts and Shortest timeline for part development.	***Temporary action*** 100 % inspection CTQ parameter of incoming parts and parts should come along with inspection report to proto shop If any quality problem occurs to stop the work and divert the manpower to another project until the issue is resolved. ***Permanent action*** New Proto Team to be formed and do in-depth analysis to eliminate the cause.	QC Team Manager Prototype workshop QC Team	Jan 2021 Dec 2021

Further, the LSS team formulates a Simple Additive Weighting (SAW) method that helps to prioritize the jobs based on the criteria, which job should be done first, followed by the rest (Memariani et al. 2009). These criteria are also essential to the business process as they have better clarity on the upcoming jobs and prioritized jobs. SAW is a simple multi-criteria decision-making approach that involves the additive property for calculating the final score of each alternative (Eq.1). In the SAW technique, the final score of each project is calculated using the weight of the criteria score (refer to table 7), and the projects are ranked based on the weight of scores (table 8).

$$P_i = \sum_{j=1}^{k} w_j . r_{ij} \quad ; \quad i = 1, 2, \ldots, m \qquad \text{(Eq. 1)}$$

Where r_{ij} is the score of the i^{th} alternative concerning the j^{th} criteria, w_j is the weighted criteria.

Table 7 Weight Criteria for Job Prioritization

	Criteria	Priority	Project Requirement	Cost Priority	Environmental Impact	Motorised Unit	Customer Need
Project	**Score**	**(< 30%)**	**(< 10%)**	**(< 20%)**	**(< 10%)**	**(< 10%)**	**(< 20%)**
1	Bus	20	10	10	5	5	15
2	N Truck	30	10	15	10	5	10
3	ICV	10	10	17	9	5	15
4	C Truck	10	10	12	7	5	20
5	Engine	10	10	14	2	5	15
	Max	30	10	17	10	5	20

Table 8 Prioritizing of Jobs with Scores, Weight age, and Ranks

	Criteria	Priority	Project Requirement	CP	EI	MU	CN	Weight	Rank
Project	Score	0.3	0.1	0.2	0.1	0.1	0.2		
1	Bus	0.67	1.00	0.59	0.50	1.00	0.75	**72**	**3**
2	N Truck	1.00	1.00	0.88	1.00	1.00	0.50	**88**	**1**
3	ICV	0.33	1.00	1.00	0.90	1.00	0.75	**74**	**2**
4	C Truck	0.33	1.00	0.71	0.70	1.00	1.00	**71**	**4**
5	Engine	0.33	1.00	0.82	0.20	1.00	0.75	**63**	**5**

Based on the saw analysis from table 7, the project N truck has priority in the Prototype workshop. The LSS team used Kata (*act of converting thinking to tangible daily actions*) and Genchi Gembutsu (*Emphasize GO and SEE the Process*) to create a daily management guideline for the proto shop activities (Anjos, 2009; Rother, 2009). Because both Job card and System process in proto activities can be addressed with a quick action group. Further, the task scheduling ensures the in-house experts were assigned to the specific projects based on the priority, and the external consultants can be relieved from the proto shop leading to cost savings. Therefore, the LSS team prepared a daily management guideline (refer to figure 7), and the Prototype workshop head reviewed the daily management for the prototype workshop and approved it. The synergy from Kata and Genchi Gembutsu played a significant role in the day-to-day management. The planning team will do the plan for the week and release the weekly program to the Test Manager, Engineers, and shop floor executives. As per the plan, the shop floor executive assigns the associates and carries out the work; in parallel, the Test managers and engineers will work on the design verification process and the checking process with the leap (Quick action group) for the proto building. The GAP analysis will give necessary information regarding corrections and takeaways, which will be critical for future jobs.

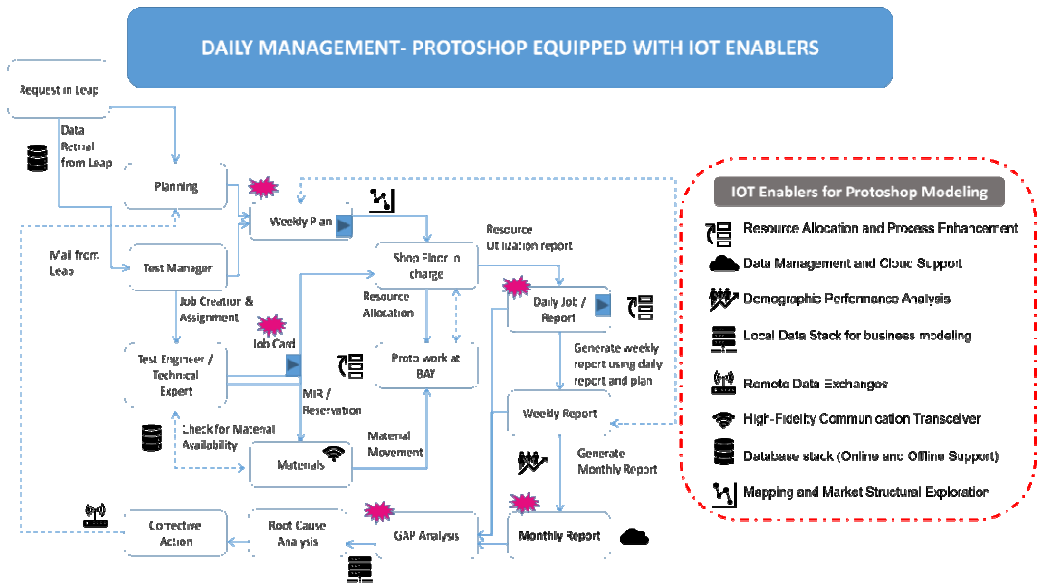


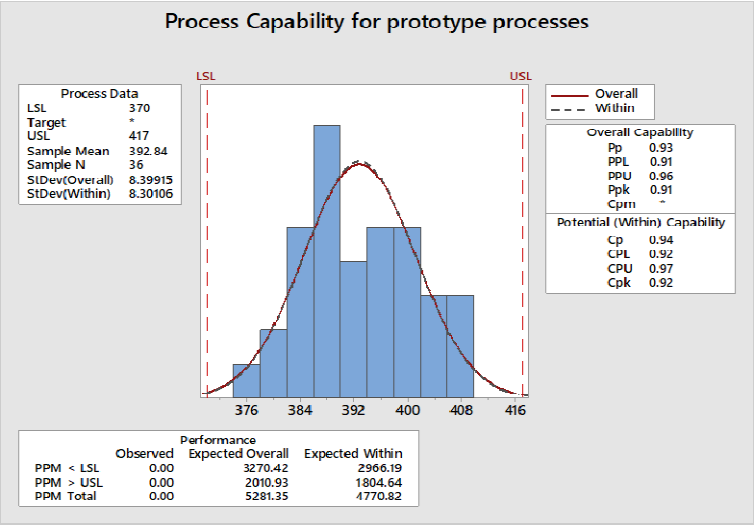
Figure 7 IoT Driven Daily Management

Moreover, Request-Approval- Acknowledgement- Movement remains unaltered in all the stages of the model. As the data flows through different entities in the scheme, sequential procedures will follow up for all the entered units involved in the design as per the scheduled plans. Irrespective of the Job card, all the daily and weekly updates were monitored for effective information extraction and efficient feature validation. In any adversaries in the business practices, the model flow will be cross-examined by the skill labors and resources kept as backup support in the design. All the IoT enablers shown in figure 7 takes care of the operation starting from deployment till product delivery. Systematic control and robust working module help the model to sustain in every industrial aspect in rea-time.

4.8 Control

In the control phase, the LSS team develops a control plan to stabilize the improvements. In this phase, the LSS team monitors the results and compares that with the current results (Sunder M et al. 2016). The Proto build GAP occurs for several reasons in the project, and it took several initiatives to overcome these bottlenecks. The LSS team reviewed the status of proto build to sustain the development, as shown in figure 8. IoT-driven daily management provides process automation, leading to localization and time stamping of the proto conversion.

Further, Triaging reroutes unwanted jobs and removes bottlenecks making the Process simple and thereby reducing the lead-time to 390 with a deviation of 20 minutes which is shown in figure 8. Also, process capability analysis indicates that the C_{pk} =0.92, proving that the Process is capable and the IoT deployment minimized the TAT for the prototype processes. Also, the deviation of 20 minutes is achieved, which is plotted in the I chart (Refer Figure 8), supporting that the process variation is minimized.



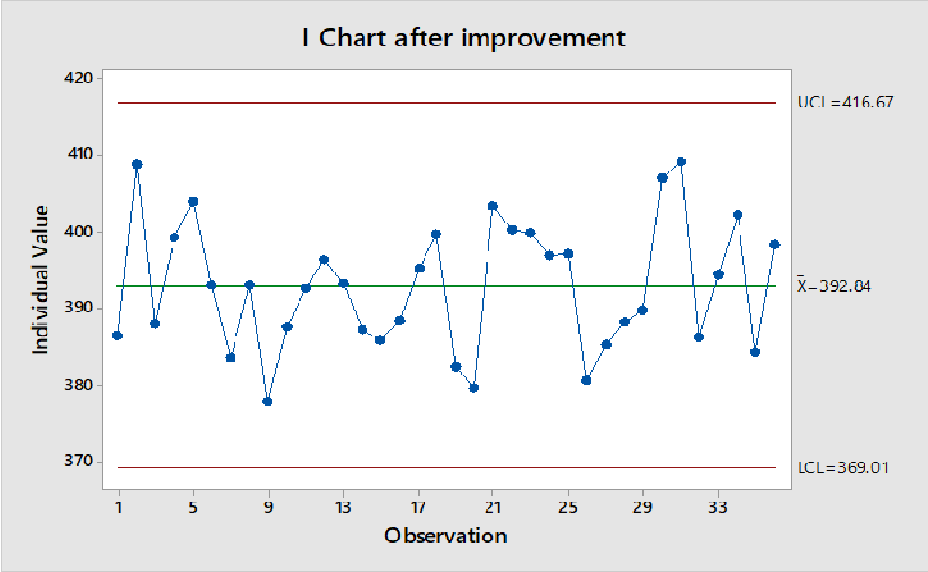


Figure 8 Prototype Process with IoT Deployment

4.9 Sustain

The LSS team created a routine for the flow of events of the Test Manager, Engineers, and shop floor executives who will reduce the time gap using GAP analysis and cause analysis, thereby making corrective actions for the defects or errors. With the help of daily, weekly, and monthly plans, the movement of materials to the bay is made clear for all levels of employees. From the data observed, the LSS team observed the average no of jobs in each of the three segments discussed as below,

Average Jobs of New proto build	= 05
Average Jobs of Proto conversion	= 13
Average Jobs of Miscellaneous	= 27
The average demand for Jobs per month	= 45

'If the average demand for these values calculated exceeds, then there is a need to do more analysis to reduce the downtime, improve PN, and ensure that the CNA is met without any failures. More Manual data processing and recording of proto build activities are automated using software packages to increase productivity and efficiency. The LSS team created a feedback system (Refer to figure 9) to understand the issue in the proto build. It gave weekly updates to the proto lead and design team for continuous improvement for prototype conversion activities.

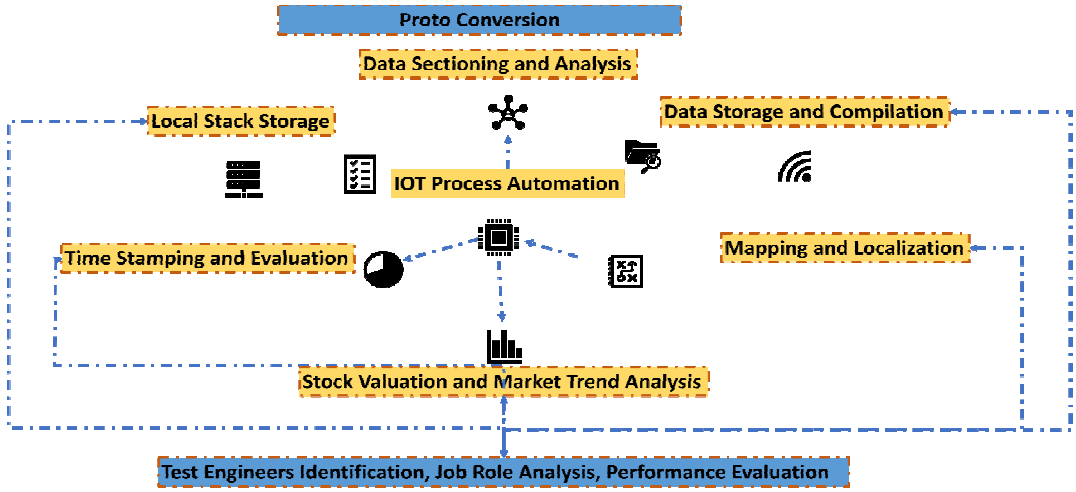


Figure 9 IoT Ecosystem for Proto Conversion

Further, the LSS team will coordinate with process planning and implementation. Further, the cost of investment in IoT setup is presented in table 9, thereby promoting digitalising in prototype manufacturing.

Table 9 Cost of IoT Elements

Element	Zone/ Region	Skill Set	Operating Cost	Maintenance	Lifetime/ Warranty
Sensor	Full Area	Critical	Rs. 30,000-50,000	Replacement	2-3 Years
Connectivity Modules (Wi-Fi, Zigbee, LAN)	Highly Sensitive Areas	Medium	Rs. 50,000-90,000	Routine Service	5 Years
Network Gateway	Full Area	Medium	Rs. 45,000	Routine Service	5-8 Years
Data Stack	Full Area	High	Rs. 25,000-30,000	New Purchase	Lifetime
User Interface (Computer, Mobiles, etc)	Full Area	Medium	Rs. 70,000	Routine Service	5-8 Years
Cloud	Full Area	High	Rs. 40,000-55,000	New Purchase	Lifetime
Embedded Controllers	High Sensitive Areas	Critical	Rs. 80,000	Replacement	2-3 Years

5 Discussion of Findings

The present work focuses on digitalizing IoT with LSS project management. To achieve this, the study used the enhanced DMAIC approach known as "SDMMAICS" with IoT. Then the integrated model was tested in the prototype workshop of a commercial vehicle manufacturer. Moreover, the present work provides a dynamic approach to adapt to dynamics in the commercial vehicle manufacturing process. Findings from the study show that implementing IoT integrated LSS approach has resulted in a rise in the number of jobs for the new proto build from five to seven over five months.

Similarly, for Proto conversion projects, a gap of one between plan vs. actual is achieved compared to a previous gap of four over four months. Also, in Miscellaneous projects, a drastic reduction in the gap between the plan and actual is achieved in four months, which was thirteen previously. So from these results, it clear that LSS plays a significant role in new product development, leading to a cost saving of 5500 USD/month (by relieving the external consultants). From table 8, prioritizing of Jobs is given for N Truck. This Prioritizing is achieved with the help of SAW – A simple additive weighting method done by the prototype workshop divisional manager. The case findings make the efficient usage of materials and time correctly so that the cost incurred can be minimized. The various causes for the Gap plan vs. actual (effect) are analyzed, and the improvements are provided.

Further, synersing the Kata and Genchi Gembutsu for daily management was adequate, and the proto shop process flow was streamlined using the IoT-driven day-to-day management. Further, the TRIAGING Process reduces the delay and Congestion in projects, which managers will analyze. The TRIAGING reroutes the defective jobs so that it will not create a bottleneck, assigning new proto build and Proto conversion jobs to engineers and other Miscellaneous jobs to Engineers and associates to reduce overall lead-time. Further, process automation and time stamping ensure better information flow for proto conversion. Later, it was validated using process capability analysis (Cpk =0.92), proving that the Process is capable. The IoT deployment minimized the TAT in the prototype processes by reducing the lead time by 60 minutes. Finally, the study has reported the cost of IoT devices, promoting practitioners to digitalize the IoT with LSS projects. Therefore, integrating IoT with LSS aids in improving the overall Process of the prototype building, thereby increasing the profit by decreasing the costs and improving the Process's efficiency.

6 Conclusion

The study reported the impact of LSS in process improvement for Commercial vehicles, using IoT, which is the first of its kind. The proposed approach in the prototype workshop for a particular product (N Truck) is applied in the new product development process. Besides, simple mechanisms like SAW, triage, etc., have been provided to disseminate shop floor issues. The resulting case-based study illustrates how the LSS methodology can be used to facilitate the new product development process. The main contribution can be unfolded into two parts:

Creating a structured approach for process execution in the prototype workshop. Through GAP reduction, engineers were assigned to the project, making them self-sustained, leading to a cost saving of 5500 USD. Such as many studies, the present study has some Limitations. The case study found that LSS serves a simple yet effective approach for business excellence in the process improvement for the commercial vehicle segment. Through the LSS Methodology, the productivity of the proto shop has increased with better cost savings.

6.1 Practical Implications

The study establishes the advantages of blending IoT with the SDMMAICS approach compared with the counterpart of DMAIC. The IoT ecosystem was proposed for prototype processes to minimize the lead time and complete the projects in time. Further, the prototype shop head uses IoT-driven daily management for the prototype building activities. Also, step by step sequence for proto conversion is proposed in sustain phase. Further, the case emphasizes that practitioners choose daily management (Synergizing Kata and Genchi Gembutsu) for cross-functional operations.

6.2 Theoretical Contributions

This study enables new thinking of the application of LSS in the Prototype workshop setting, which was perhaps not explored in the recent literature. Moreover, the study also paves the way for future researchers and students to improve the automated data processing in the Prototype workshop to reduce the products' defects and overall cycle time to enhance efficiency and effectiveness contributes to the literature in the quality domain. Though there has been researching on the application of LSS in automotive design, this study uses IoT and LSS to improve the Process, which initially creates a structured planning approach in a Prototype workshop setting and contributes to smart manufacturing pieces of literature.

6.3 Limitations of the Study

The study has its limitation, such as the proposed work integrated IoT and SDMMAICS. However, future researchers can link blockchain for introducing roles and responsibility for data collection in the Measure phase. Further, the study focused on a particular product family for the analysis. Also, employee's skill was not evaluated. Future researchers can concentrate on assessing the employees' abilities in the workplace.

Moreover, researchers can incorporate Value Stream Mapping (VSM) to get an overview of the present and future state of the case. Due to funding constraints and time limitations, the researchers could not incorporate VSM in the present study. Further, the study can be expanded to the other product family. Moreover, the current structure is not flexible, with no clear roles for the employee. Based on the reviews from the scholarly articles discussed above, it is evident that only a few articles have addressed process improvement using IoT & LSS in the context of the commercial vehicle segment.

Moreover, most of the case studies were focused on products and services, and only a few have tried to explore the processes of the proto building in a Prototype workshop practically. The current study presents a single case to understand the application of LSS in a prototype setting. Several such cases could enable generalization. The study also paves the way for future researchers and students to improve the automated data collection in the Prototype workshop to reduce the quality-related defects and TAT for Proto conversion. Finally, using LSS tools in this case study is limited to its appropriateness and availability of data/process information. A variety of visualization tools need to be integrated into the control phase to develop dashboards for process control and decision-making.

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The Study of Internet Uses, Internet Addiction, and Magnitude of Consequences among Young Students

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Abstract

Purpose-*The current study investigates the prevalence, determinants, and impacts of internet addiction among young Indian students as they are the most vulnerable to Internet addiction in the population.*

Design/Methodology/Approach*-The one-way ANOVA and multiple regression approaches were applied to evaluate and validate the theoretical framework using questionnaire-based survey data from 626 young Internet users (students) from north part of India.*

Findings*-The study finds evidence of internet addiction among Indian students, which is linked to internet misuse as well as physical, psychological, and behavioral symptoms.*

Research limitations/Implications-*The study emphasizes the psychological concerns that arise as a result of increased internet usage, both as a cause and as an effect. In contrast to many other studies, the current study found that females are more addicted to the internet than males.*

Originality*-Internet addiction is described as unregulated and poorly controlled internet use or behaviors that cause impairment, stress, dimensionally detectable depression, social isolation, and anguish. Although, a plethora of studies also affirms that the exponential growth of Internet technology and particularly its striking use in every sphere of life has negative consequences that led to pathological conditions (Internet Addiction) among the users.*

Keywords: *Internet Uses, Internet Addiction, Indian Students, Addictive Behavior, Students, Mental Health, Demographic Analysis.*

1. Introduction

As technological appliances become progressively embark on our lives, they will be embedded, concealed and we will tend to integrate with them. This merging of humanity and technology in the coming generation will be inescapable, leading to high implications on various spheres of lives of people. The magic created and the ability to brace any of the information by just

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interacting with a machine were unintelligible to anybody decades ago. And while making technology ubiquitous in the personal and professional sphere, understanding how we interact with, utilize it and dependency is increasingly important. There are ongoing debates and discussions on how to classify the behavior which is typically characterized by excessive use of non-work-related technology which is related to the internet more specifically. This utilization is recognized as an addiction. The intense utilization of internet activities such as gaming, blogging, surfing, chat rooms, shopping, and pornography at the cost of utilizing the time productively is classified as an addiction disorder, which is used in many studies like Internet Addiction Disorder (IAD), Problematic Internet Use (PIU) and Compulsive Internet Use (CIU). This internet addiction is most generally described and an impulse control disorder, similar to pathological gambling but not necessarily involves any intoxicating drugs. Reports show a stark rise in the number of internet users from 394 million in 2000 to 1 billion in 2005 to 4.15 billion in December 2017. Depression, poor attention, extreme anxiety, psychomotor agitation, salience, mood modulation, obsessive thoughts, insomnia, etc. are just a few of the symptoms of these diseases.

With regard to the above, World Health Organization (WHO) is to include "gaming disorders" into the International Classification of Diseases. This step by WHO recognizes and highlights the growing and serious problem of internet addiction. A study by the Chinese Academy of Science draws the similarity of the brain changes between an internet addict and a drug or alcohol addict (Zou et al., 2012). Internet addiction is thought to have widespread negative effects that affect many areas of life, including the physical, emotional, psychological, occupational, and interpersonal. The young people who spend too much time online and neglect their families, careers, social lives, and most importantly their interests, however, tend to be negatively impacted. Cheng and Li (2014) report the alarming nature of internet addiction, whether or not it is codified within a clinical framework, but recognizing the fair potential of the problem. Various studies also highlight the need for serious attention towards this crisis of internet addiction by academicians, health experts, professional institutions, society as well as the government (Kuss and Lopez-Fernandez, 2016; Cash et al., 2012; Schell, 2016; Young and De Abreu, 2017).

In light of this, the following research questions were addressed in this study:
RQ1: What are the roles of Internet addiction among students?
RQ2: How gender is differentiated from internet addiction by demographic analysis?
In light of the above discussion, the current study has the following objectives:

1. To examine the extent of internet addiction among north part of Indian students such as Delhi, Haryana, Punjab, Uttarakhand, and Uttar Pradesh regions students.
2. To investigate the degree of association among the sampled respondents, there was a link between gender and internet addiction.

3. To assess the uses pattern of the internet and other social media by the sample respondents and to suggest the strategies to cope with the problem of internet addiction.

The structure of this research is discussed in the following sections. Section 2 discusses the review of the literature and the research methodology part is discussed in section 3. Section 4 outlines the data analysis and results followed by the discussion and conclusions in Section 5.

2. Literature Review

There has been a wide range of literature on internet addiction from combining the term addiction with technology by Silver and Aldrich (1970) to Young, who did an extensive study on internet addiction. The introductory significant study of addiction with computers emerged in 1989 in a book by Margaret Shotten, in which she described few of the UK students are enthralled by the machines to the prohibition of other activities (Margaret, 1989). Griffiths (1995) concludes by referring to video games, computers, fruit machines by saying that there's little doubt that activities involving human-machine interaction will continue to grow in popularity, and that products like interactive CDs and virtual reality consoles will expand the amount of possible technological addictions (and addicts). Ivan (1995) mentioned internet addiction as an informal phrase to describe its excessive usage.

Dr. Kimberly Young first proposed the term "internet addiction" at the American Psychological Association's Annual Meeting in August 1996. (Young, 1996a,b), leading to many controversies on the usage of the term "addiction" as they believed the term can only be used when a person is injected with a high dose of drug. To make the improper use of the internet and the unrestrained use of internet technology more understandable, researchers have developed the phrase and idea of internet addiction (Seaman, 1998; Goldsmith, 2000; Kraut et al., 2002; Griffiths, 1997; Schneider, 2003; Romano, 2013; Cui et al., 2006; Pratarelli and Browne, 2002; Shaw, 2008; Shepherd, 2005; Kandell, 1998; Shotten, 1989; Aldrich, 1979; Zhang, 2010; Thatcher, 2008; Leung, 2004; Young, 1998a). Researchers also brought out the strand which recognized various types of disorders developed due to internet addiction similar to drug or alcohol addicts (Schell, 2016; Scherer, 1997; Fabian, 2001; Lim *et al*., 2008), drugs (Kaltiala-Heino, 2004; Kraut, 2002; Krishnamurthy, 2015; Romero *et al.,* 2010; Kuss and Lopez-Fernandez, 2016; Cash et al., 2012; Bell *et al.,* 2011), gambling or betting (Ozturk *et al.,* 2007; Yeong-Mi, 2014; Park *et al.,* 2010; Vyjayanthi, 2014; Walker, 1989s; Yellowlees, 2007), sex or pornography (Petrie and Gunn, 1998; Leung, 2003; Boies *et al.,* 2004a,b; Carnes, 2001; Harrill 2017; Carnes, 1999) or other irresistible or compelling attitude (Walker, 1989; Truer *et al.,* 2001; O'Reilly, 1996; Greenfield, 1999; Carnes, 1999; Carnes, 2001; Charlton, 2007; Black *et al.,* 1999; Thatcher et al., 2008; Hayley 2016). Addicts significantly reported unfavorable and unpleasant repercussions from excessive internet use, a predisposition to use the internet even when offline, and mixed sentiments of guilt and worry about how much time they spend online when compared to non-addicts (Egger, 1996; Scherer, 1997; Kuss and Lopez-

Fernandez, 2016; Cash et al., 2012); hiding the fact about time spent on internet to their peers (Kandell, 1998; Wang, 2008; Park and Floyd, 1996; Hing 2011).

Five internet overuse-related problems were indicated by Brenner (1997) such as time mismanagement, lack of sleep, missed meals, etc. Excessive internet use has been linked to personal, professional, and occupational problems, as well as a lack of sleep and meal skipping, in both a healthy and bad way, according to studies (Young, 1998a,b,c; Young, 1999; Scherer, 1997). Various other studies also highlighted common problems created by unrestrained internet use like disrupted marriages or marital issues (Lin *et al.,* 2016; Putnam, 2000; Schneider, 2003; Zahra et al., 2015; Armstrong *et al.,* 2000; Penn, 2015; Ko *et al.,* 2005a,b; Hops *et al.,* 1990), monetary issues (Cooper and Sportolari, 1997; Brenner, 1997; Kaltiala-Heino *et al.,* 2000; Lavin *et al.,* 2000; Pratarelli *et al.,* 2002; Caplan, 2002), these all discussed the negative effects of addiction to the internet in the personal as well as professional lives.

Till date, accessing the interactions between personality and different types of potentially problematic usage of the internet has been very less. These variables may permit discerning factors, both risks along with protection. Taking into consideration the gender difference perspective, men are proved to be more internet addict as compared to women in developed or high tech economies proved by many clinical samplings and online studies (Shaw and Black 2008; Roger, 2009; Kaltiala-Heino and Lintonen, 2004; Peter and Shyana, 2007; Young, 1998; Young 1999; Shapira *et al.,* 2000; Breedon, 2009; Kang, 1999). Numerous studies have attempted to measure how much time people spend online in order to assess and analyse the issue of addiction, but they have also highlighted how frequently students now use Wi-Fi or the internet. Students are found to rely strongly on the internet for academics' purposes, updating the news all over the world, communicating, and entertaining them. This proves internet addiction a multidimensional and multifaceted concept that should be explored in a wider perspective to get a hold of a wider understanding of the issue. The research framework has been shown in Figure 1.

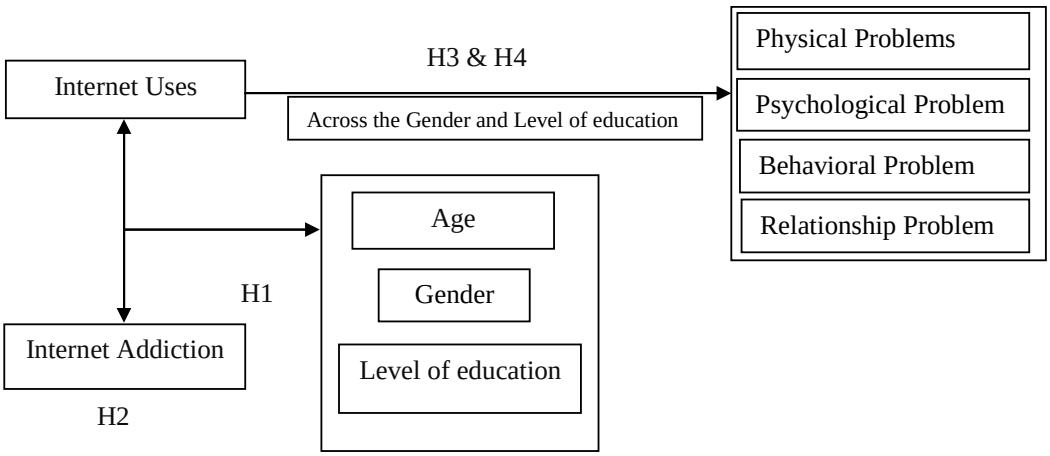

Figure 1 Research Framework

Based on the above discussion, the following four hypotheses are suggested:
H1: The demographic analysis across the age, gender categories, and level of education of respondents that have no significant difference for Internet uses and internet addiction.
H2: Internet overuse has no significant impact on Internet addiction among students.
H3: There is no significant difference in the magnitude of consequences such as physical, psychological, behavioural, and relationship problems of internet users across the gender categories of respondents.
H4: There is no significant difference in the magnitude of consequences such as physical, psychological, behavioural, and relationship problems of internet users across the level of education of respondents.

3. Research Methodology

The current research is based on both primary data. This study employed a descriptive research design. The survey with the target population was conducted using a non-probability sampling method. To assess the hypotheses proposed for the study, a survey of the target population was conducted. There are several scholarly articles that refer to the suggested study topic, including works that identify some of the variables in question described below. (Lin et al., 2011; Sharma et al., 2016). The Internet Addiction Test (IAT) established by Dr. Kimberly Young (1998) was used in this study to assess the respondents' level of internet addiction. It examines how their Internet use affects their everyday activities, social lives, productivity, sleeping patterns, and sentiments. Online surveys were used to collect information. The structured questionnaire was designed to cover different dimensions of Internet uses, internet uses pattern in class, Purpose of Using the Internet in the class, Nature of Internet Addiction, Internet Over Uses, Consequences of excessive use of the internet and posted to users will be able to participate in an online survey produced from October 2019 to February 2020 on Google Forms. The respondents were encouraged to participate in the survey via email and by publishing invites on well-known websites, instructing potential respondents to complete the questionnaire on various social media websites. Variables for social media marketing, purpose, magnitude, and important consequences were identified through the review of relevant literature. There were three sections to the survey questionnaire. The demographic profile of respondents was the first section of the study. The second section of the questionnaire focuses on the amount of time and effort spent on the internet, as well as the intensity with which it is used. The third part of the questions related to various consequences of internet addiction in terms of physical disorders, psychological disorders, behavioural problems, and Relationship Problem among students' Respondents was asked to express their opinions based on their level of agreement with 41 qualities (seven attributes for lifestyle product categories, nine measurement variable related to social media marketing.

The validity of the survey instrument was assured by giving the initial questionnaire to a panel of experts and faculty members. This was intended to assure the validity of its content,

the accuracy of its interpretation of the objects, and to ensure its ties with the study objectives. To confirm the reliability, the questionnaire was tested on a pilot basis using 50 respondents, representing 8 percent of the total sample size, who were considered the research population representatives. The alpha value of Cronbach's alpha was found to be 0.906 which indicated the questionnaire's appropriate level of reliability. The questionnaire was sent to 2,500 respondents. Researchers received 700 responses. After editing, 626 responses were considered suitable and used in this study. 74 responses were rejected which were either inaccurate or insincerely responded to. Using SPSS 22 software, the data was organized, tabulated, and analyzed methodically. To achieve the objectives and test the hypothesis of whether the extent of internet addiction and its consequences on students differs significantly across gender categories and level of education of students (UG & PG), data analysis includes descriptive statistics using SPSS 22 and ANOVA analysis and other appropriate statistical tools. The proposed research framework employed in this study is shown in Figure 2.

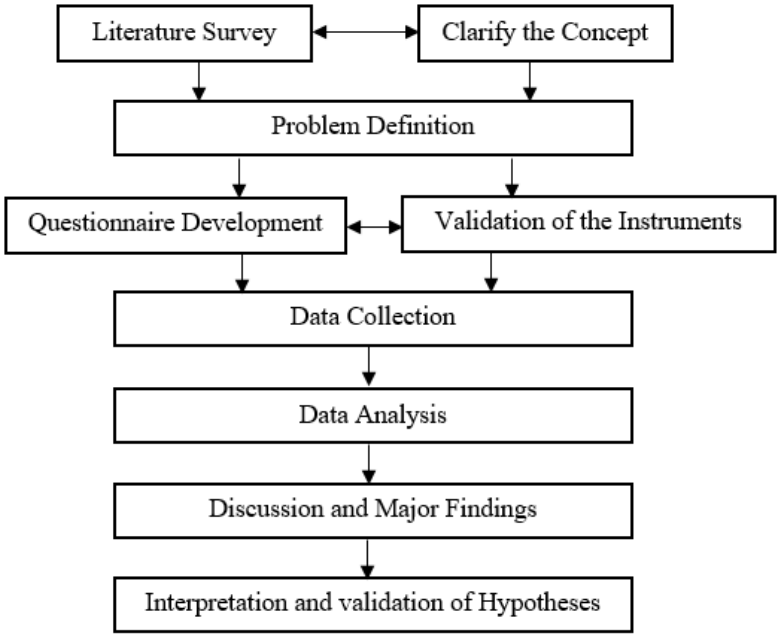

Figure 2 Proposed Research Framework Employed in this Study

4. Data Analysis and Results

4.1 Demographic Profile

The demographic information presented in table 1 indicates that the sample is dominated by the respondents in the age of 20-25 years as is indicated by 61% of respondents in the sample. The data we received from the north part of Indian students such as Delhi, Haryana, Punjab, Uttarakhand, and Uttar Pradesh regions students. Another 25.7% of respondents were found to be in the age group ranging from 15-20 years. 12.6% of respondents indicated their age in the group of 25-30 years. Very few respondents (0.6%) were indicated their age

above 30 years. The majority of the respondents are from the male categories (61.3%. remaining 38.7% of respondents are from female category respondents. The majority of the respondents (60.2%) are post-graduation category respondents and 39.8% of students are doing undergraduate courses. More than two-thirds of respondents (68.5%) indicated that they are living with their family and the remaining 31.5% indicated that they are living in a hostel with a friend or in a rented house. The majority of the students belong to lower-income category respondents as was indicated by 56.4% of respondents. 41.2% of respondents are from the middle-income group and the remaining 2.4% belong to the upper-income group of respondents. Information related to the nature of the relationship indicated that 74.4% of respondents are single category respondents. 19.5% of respondents are found to be in a relationship and the remaining 6.1% of respondents are in a complicated relationship.

Table 1 Demographic Profile of Respondents (N = 626)

Demographic Characteristics		Frequency	Percentage
Age	15-20 Years	161	25.7
	20-25 Years	382	61.0
	25-30 years	79	12.6
	More than 30 Years	4	0.6
Gender	Male	384	61.3
	Female	242	38.7
Education level	Graduation	249	39.8
	Post Graduations	377	60.2
Nature of Accommodation	With Family	429	68.5
	Hostel with friends/rent	197	31.5
Income Categories	Upper Class	15	2.40
	Upper Middle Class	258	41.2
	Lower Middle Class	353	56.4
Nature of Relationship	Single	466	74.4
	In relationship	122	19.5
	Complicated	38	6.10

Table 2 Demographic Characteristics of Internet Uses Pattern

Demographic Characteristics		Frequency	Percentage
Average Hours of Uses	0-2 Hours	105	16.8
	3-4 hours	261	41.7
	5-6 hours	97	15.5
	7-8 hours	72	11.5
	9-10 Hours	44	7.0
	11-12 hours	36	5.8
	13-14 hours	7	1.1
	15-16 hours	4	0.6

Practices of Switching of Notification in class	Yes	536	85.6
	No	90	14.4
Can live without internet	Yes	233	37.2
	No	293	46.8
	can't say/ do not know	100	16.0
Can the internet be regulated	Yes	288	46.0
	NO	160	25.6
	Can't Say	178	28.4
Uses of Internet in the classroom	never	280	44.7
	Sometimes	294	47.0
	Most of the times	52	8.3
Visiting pattern of a porn site in a week	1-3 time	440	70.3
	4-6 times	146	23.3
	7-9 times	40	6.4
The feeling of Internet Addiction	Not at All	55	8.8
	Not much	163	26.0
	Somewhat	257	41.1
	Very Much	151	24.1

The information presented in Table 2 indicates the Internet Uses Pattern among the students. It is observed that the majority of the respondents use internets sites up to 4 hours daily as combined this was indicated by 48.5% of respondents in the sample. Further, 15.5%, 11.5%, 7.0%, 5.8% 1.1% and .6% respondents respectively use internet ranging from 5-6 hours, 7-8 hours, 9-10 Hours, 11-12 hours, 13-14 hours, and 15-16 hours daily. Looking at the trend of Practices of Switching of Notification in class, it is observed that 85.6% of respondents keep their internet notification on in the class as compared to 14.4% keep their mobile off in the classroom. Looking at the trend of the student whether they can live without internet, it is observed that 37.2% of respondents are positive and can live without internet. Whereas 46.8% of respondents have indicated their inability that they cannot live without the internet. And 16% of respondents indicated that they cannot comment or they do not know about it. Looking at the trend of whether the internet can be regulated in the class, it is noticed that 46.0% of students are of the opinion that yes it can be regulated whereas 25.6% of the student said no and 28.4 % of students were not sure on it. Looking at the Uses of the Internet in a classroom, it is found that 44.7% of students indicated that they never use mobile in class. As compared to this 47% of respondents indicated that they sometimes use the internet in the class whereas 8.3% of students indicated that most of the time they use the internet in the class. Visiting of the porn site is becoming a serious issue among the student. The study indicated that 70.3% of respondents visit porn sites 1-3 times a week. 23.3% of respondents indicated that they visit 4-6 times a week. 6.4% of respondents indicated that they visit 7-9

times a week. Pattern regarding Feelings of Internet Addiction indicates that 8.8% of respondents indicated that they do not feel internet addiction at all. 26% of respondents indicated that feeling of internet addiction is not many 0.4.1% respondents somewhat feel internet addiction whereas 24.1% respondents very much feel about internet addiction.

4.2 Analysis of Internet Users over Internet Addiction

The Internet and its various educational applications have gained popularity for students who search for different information for academic purposes. The Internet is a source of extensive knowledge that everything can be accessed quickly and easily. Reliability (α) was calculated for all the measurement scales and found to be 0.781 (Table 3) indicating that constructs are reliable enough to go for further statistical analysis. Looking at the various Purpose of Using the Internet by the students in the class, it is observed that Informing others about the class are the most common internet uses in the class as it has scored the highest mean of 2.1981 and SD=1.02562. It was followed by the Texted/checked mailbox or online status while in class with a mean of 1.9649 and SD=1.06224. Receiving a sexually suggestive nude or nearly nude photo or video has scored the lowest mean of 1.1390 with SD=.47482. It is followed by online gaming in the class with a mean =1.3626 and SD=0.88966.

Table 3 Purpose of Using the Internet in the Class: Descriptive Statistics (n=626)

	Mean	Std. Deviation	Reliability(α)
Texted/checked mailbox or online status while in class	1.9649	1.06224	0.781
Verifying (with the internet) what your teacher is teaching in the classroom	1.8067	1.08636	
Informing others about the class	2.1981	1.02562	
Downloading or receiving movies/videos/music/ photos etc.	1.6470	1.01743	
Sending video/music, images, etc. to someone else.	1.7380	1.01748	
Online gaming	1.3626	.88966	
Sent a sexually suggestive nude or nearly nude photo or video	1.1294	.55788	
Taking picture or selfie and uploading on the net	1.5767	.88978	
Receive a sexually suggestive nude or nearly nude photo or video	1.1390	.47482	
Any other	1.2668	.78020	
Valid N (listwise)			

Table 4 Nature of Internet Addiction: A Descriptive Statistics

Causes of Internet Overuses	Mean	Std. Deviation	Reliability(α)
Internet Addiction (N=626)	2.0815	.71876	0.929
CIO1	2.4425	1.16099	
CIO2	1.9808	1.11554	
CIO3	1.8722	1.25333	
CIO4	1.8067	1.02732	
CIO5	1.9569	1.35401	
CIO6	2.0863	1.24151	
CIO7	2.3275	1.24571	
CIO8	2.2460	1.13850	
CIO9	2.0559	1.18460	
CIO10	2.2684	1.38732	
CIO11	2.1470	1.16515	
CIO12	2.2796	1.26370	
CIO13	1.9649	1.08608	
CIO14	2.1198	1.26365	
CIO15	1.8626	1.17316	
CIO16	2.3403	1.27783	
CIO17	2.2188	1.32001	
CIO18	1.9808	1.21311	
CIO19	1.7077	1.06095	
CIO20	1.9665	1.06905	

The extensive use of the internet and other social media sites and their effect on our lives is becoming ever more important and undeniable. Life without the Internet is certainly very distressing and awkward. Internet innovation is the result of the rapid advancement of science and technology. It can be good or bad for the students depending on how they use it. Whether we do it prosaically or favorably it can be good and it can be evil if we use it immorally or antisocially. Although there is no easy way to escape the growth of science and technology, it is now unavoidable and vital in school to teach a constructive and moral attitude toward the usage of the Internet. Table 4 indicates the frequency of statements among the participants in the study. Reliability(α) was calculated for all the measurement scales and found to be 0.929 (table 4) indicating that constructs are reliable enough to go for further statistical analysis. It is observed that statements like "*I remain online longer than you intended to*" have scored the highest mean of 2.4425 with SD=1.16099. it was followed by a statement like" I find myself saying "*just a few more minutes*" when online" with mean= 2.3403and SD=1.27783. the statement like "I choose to spend more time online even after going out with others" has scored the lowest mean of 1.7077 and SD=1.06095. it is followed by the statement like "*I intend to form new relationships with fellow online users*" with mean =1.8067 and SD=1.02732.

The majority of the participants received scores that varied from rarely to never to occasionally indicating a moderate level of addiction among students.

Table 5 Causes of Internet Overuse: A Descriptive Statistics

(N=626)	Mean	Std. Deviation	Reliability(α)
Internet Over Uses	2.8315	0.79460	0.867
IOU1	2.6949	1.19781	
IOU2	2.3307	1.20037	
IOU3	3.2236	1.36978	
IOU4	3.0879	1.28385	
IOU5	3.3722	1.23046	
IOU6	2.1262	1.05454	
IOU7	2.8722	1.12980	
IOU8	2.8435	1.26026	
IOU9	3.2508	1.39234	
IOU10	3.3019	1.37982	
IOU11	3.4265	1.41258	
IOU12	2.1390	1.18586	
IOU13	2.1374	1.20012	
IOU14	2.5144	1.64456	

In many ways, the Internet has made life easier, such as providing easy access to information and pleasure. When used excessively, however, it can result in melancholy, preoccupation, anxiety, and even isolation, all of which are indications of Internet addiction. Based on a review of literature, some of the important causes of internet overuse were identified and students were asked to rate it according to their preferences. The mean and standard deviation of all the causes of internet overuse were calculated and presented in table 5. Reliability(α) was calculated for all the measurement scales and found to be .867 (Table 5) indicating that constructs are reliable enough to go for further statistical analysis. It is observed that Sexual exploration has one of the important reasons disclosed by students with 3.4265 and SD=1.41258. this was followed by the statement like" I want to escape harsh realities of life" with mean of 3.3722 and SD of 1.23046. Leisure time or Free time has scored the lowest mean of 2.1262 and SD=1.05454.

Table 6 Consequences of Excessive Use of the Internet: A Descriptive Statistics

Consequences(N=626)	Mean	Std. Deviation	Reliability(α)
Physical Problems	2.2764	0.98478	0.917
PHP1	2.5399	1.24547	
PHP2	2.4920	1.26394	
PHP3	2.3450	1.28341	

PHP4	2.1470	1.35202	
PHP5	1.7824	1.01937	
PHP6	2.5808	1.29853	
PHP7	2.3968	1.28452	
PHP8	1.8992	1.10117	
PHP9	2.3024	1.35392	
Psychological Problems	2.1800	1.01878	
PSP1	2.5968	1.36250	
PSP2	2.4272	1.28909	
PSP3	2.0944	1.11475	
PSP4	2.1040	1.25463	0.938
PSP5	2.1408	1.28453	
PSP6	2.0128	1.09038	
PSP7	1.9904	1.12371	
PSP8	2.0736	1.20137	
Behavioural Problems	2.1465	.91039	
BP1	2.3792	1.18290	
BP2	1.9552	1.07473	
BP3	1.8528	1.07153	
BP4	2.3856	1.23910	0.907
BP5	2.1920	1.23838	
BP6	2.0976	1.24746	
BP7	2.2944	1.26961	
BP8	2.0784	1.09278	
BP9	2.0832	1.03595	
Relationship Problems	1.7688	.81293	
RP1	1.8784	1.10271	
RP2	1.7520	1.02732	
RP3	2.0160	.99183	
RP4	1.9712	1.03580	0.936
RP5	1.7136	1.04677	
RP6	1.6160	.97224	
RP7	1.7040	.97586	
RP8	1.4992	.82455	

Excessive use of the internet and other social media sites has many adverse effects on mental as well as physical disability and disturbances. Based the review of the literature and past research finding the construct of consequences were identified. These include physical problems, psychological problems, behavioural problems, and relationship problems. Further measurement variable was identified and students were asked to rate on a scale of1 to 5.

Reliability (α) was calculated for all the constructs and found to be between .907 to 0.938 (Table 6) indicating that constructs are reliable enough to go for further statistical analysis. Descriptive statistics and reliability statistics were calculated using SPSS software and presented in table 6 Data summarized in Table 6 reveals that 'Physical problem' has scored highest mean (mean = 2.2765). It is followed by 'Psychological Problems' (mean = 2.1800), 'Behavioural problem' (mean = 2.1465) and 'Relationship problem' (mean = 1.7688). Attribute 'Sleep disturbance." has scored highest with mean = 2.5808 and SD=1.29853 followed by Dry eyes/eye strain, with mean=2.5399 and SD=1.24547 and Backaches with mean =2.492 and SD= 1.26394. looking at the different measurement variables of psychological problems, it is observed that attributes like "Frequent feelings of guilt after spending too much time online" scored the highest mean of 2.5968 and Sd=1.36250 followed by "Loss of interest and participation in hobbies or activities that were once enjoyed" with mean of 2.4272 and SD=1.28909. the attributes like "Feeling calm, content, or happy only when online" has scored the lowest mean of 1.9904 with SD=1.12371. similarly, out of various measurement variables related to behavioural problems, attributes like "Loss of interest in study/work" have scored the highest mean of 2.3856 and SD=1.2391. It was followed by "Often losing track of time when online (e.g., suddenly noticing that several hours have passed when it seems like just a few minutes) "with mean =2.3792 and SD=1.1829. The attributes like "Displaying anger or resentment towards those who question how much time is spent online" have scored the lowest mean of 1.8528 and SD=1.07153. Similarly, out of various measurement variables related to a relationship problem, attributes like" Decreased time spent with family and friends" have scored the highest mean of 2.016 with SD=0.99183. it was followed by attributes like "Deceiving others about the amount of time spent on the Internet" with mean =1.9712 and SD=1.0358. the attributes like "Thoughts of "getting online", or of sexual behaviour, seep into your mind when you are not online or engaged in sexual behaviour (i.e. work, with family, etc.)" has scored the lowest mean of 1.4992 and SD=0.82455.

4.3 Testing of Hypothesis

One-way ANOVA of the combined mean of internet overuses across the level of internet addiction was calculated to assess whether there is a significant difference in the mean of internet overuses across the intent addiction of students. F value as presented in table 8(a) = 2151.630, p>.05 indicating a significant difference in the mean of internet overuses across the level of internet addiction. Further regression analysis was carried out to measure the coefficients of the linear equation between Internet overuse and Internet Addiction. The combined factor means all the measurement variables were used in analyzing internet overuse. A similar, combined mean of all measurement variables was calculated for assessing internet addiction. and then further regression analysis was carried out. Table 7a, Table 7b, and Table 7c show the results of the regression analysis. The impact of internet overuse on internet addiction found moderately significant (f=82521.042, P=.000^b, t=287.265, p=.000) and contributed 99.2% (R^2 = 0.992) to the internet addiction. The regression equation is presented as Internet Addiction =0.037+.979* Internet overuse.

The results revealed that the beta values for internet overuse are 0.979 and it has a significant effect on internet addiction, presented in Table 8(b) and hence it is concluded that internet overuse has a significant effect on internet addiction. Thus, we can say that there is no significant difference in Internet use and internet addiction across the age, gender categories, and level of education of respondents (H1).

Table 7(a) One Way ANOVA of Mean of Internet Addiction and Internet Overuses Across the Gender Categories of Respondents

ANOVA Across the Gender						
		Sum of Squares	df	Mean Square	F	Sig.
Internet addiction	Between Groups	3.141	1	3.141	5.188	.023
	Within Groups	377.739	624	.605		
	Total	380.880	625			
Internet overuse	Between Groups	3.473	1	3.473	5.540	.019
	Within Groups	391.141	624	.627		
	Total	394.614	625			

Table 7(b) One Way ANOVA of Mean of Internet Addiction and Internet Overuses Across the Age Categories of Respondents

ANOVA Across the Age						
		Sum of Squares	df	Mean Square	F	Sig.
Internet addiction	Between Groups	2.307	3	.769	1.264	.286
	Within Groups	378.573	622	.609		
	Total	380.880	625			
Internet overuse	Between Groups	2.208	3	.736	1.167	.322
	Within Groups	392.405	622	.631		
	Total	394.614	625			

Table 7(c) One Way ANOVA of Mean of Internet Addiction and Internet Overuses Across the Level of Education of Respondents

		Sum of Squares	df	Mean Square	F	Sig.
Internet addiction	Between Groups	.435	1	.435	.713	.399
	Within Groups	380.445	624	.610		
	Total	380.880	625			

Internet overuse	Between Groups	.488	1	.488	.772	.380
	Within Groups	394.126	624	.632		
	Total	394.614	625			

To test the hypothesis, one-way ANOVA of the mean of internet uses and internet addiction across the gender categories, age, and level of education of respondents was calculated and presented in table 7(a), 7(b), and 7(c). As calculated value (F=5.188, p=.023, and p>.05) internet addiction and Internet overuse (F=5.540, p=.019) is greater than the table value (3.85) and hence null hypothesis is rejected indicating that there is a significant difference in the Internet uses and internet addiction across the gender categories of respondents. however, in the case of age and level of education (table 7(b) and Table (7c) null is accepted and concluded that there is no significant difference on the Internet uses and internet addiction across the age categories and level of education of respondents. Thus, we can say that Internet over uses have no significant impact on Internet addiction among student (H2) and there is no significant difference in the magnitude of consequences of internet uses across the gender categories and level of education of respondents (H3).

Table 8 (a) One-Way ANOVA of the Mean of the Internet Overuses Across the Internet Addiction among Respondents

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	378.855	50	7.577	2151.630	.000
Within Groups	2.025	575	.004		
Total	380.880	625			

Table 8(b) Impact of Internet overuse on Internet Addiction: Regression Analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.037	.010		3.722	.000
	Internet overuse	.979	.003	.996	287.265	.000
R= .996[a] R^2 .992 F= 82521.042 P=.002[b] Std. Error of the Estimate=0.06768						
a. Dependent Variable: Internetaddiction1						

The one-way ANOVA results indicate with values of degree of freedom is 1 and the inference of observed from the table that calculated f-value is greater than the table value (3.85) in case of Physical Problems (11.113) and Psychological Problem (14.15) as against to behavioural problem (2.547) and relationship problem (1.807) at 1 degree of freedom and 0.05 level of significance. Therefore, the null hypothesis is rejected in case of the physical problem and psychological problem and it is concluded that mean of the physical problem and psychological problem differs significantly across the gender category of respondents but the

null hypothesis is accepted in the case of behavioural problems and relationship problem and it is concluded that mean of behavioural problem and relationship problem do not differ significantly across the gender categories of respondents. Table 9(a) and Table 9(b) present the one-way ANOVA of the mean consequences of excessive use of the internet across the gender and level of education categories of respondents.

Table 9(a): One Way ANOVA of Mean of Consequences of Excessive use of Internet Across the Gender Categories of Respondents

		Sum of Squares	df	Mean Square	F	Sig.
Physical Problems	Between Groups	10.605	1	10.605	11.113	0.001
	Within Groups	595.520	624	0.954		
	Total	606.125	625			
Psychological Problem	Between Groups	14.384	1	14.384	14.150	0.000
	Within Groups	633.273	623	1.016		
	Total	647.656	624			
Behavioural Problem	Between Groups	2.106	1	2.106	2.547	0.111
	Within Groups	515.075	623	0.827		
	Total	517.181	624			
Relationship Problem	Between Groups	1.193	1	1.193	1.807	0.179
	Within Groups	411.180	623	0.660		
	Total	412.373	624			

Table 9(b) One-Way ANOVA of Mean of Consequences of Excessive use of Internet Across the Level of Education of Respondents

		Sum of Squares	df	Mean Square	F	Sig.
Physical Problems	Between Groups	5.124	1	5.124	5.320	0.021
	Within Groups	601.001	624	.963		
	Total	606.125	625			

Psychological Problem	Between Groups	3.743	1	3.743	3.622	0.057
	Within Groups	643.913	623	1.034		
	Total	647.656	624			
Behavioural Problem	Between Groups	3.354	1	3.354	4.066	0.044
	Within Groups	513.827	623	.825		
	Total	517.181	624			
Relationship Problem	Between Groups	.660	1	.660	.999	0.318
	Within Groups	411.713	623	.661		
	Total	412.373	624			

The next value of one-way ANOVA results with a degree of freedom is 1 and it Inferences the observed from the table that calculated f-value is greater than the table value (3.85) in case of Physical Problems (5.320) and Behavioural Problem (4.065) as against Psychological Problem (3.622) and relationship problem (.999) at 1 degree of freedom and 0.05 level of significance. Therefore, the null hypothesis (H0) is rejected in case of the physical problem and behavioural problem and it is concluded that mean of the physical problem and behavioural problem differs significantly across the level of education of respondents but the null hypothesis is accepted in case of Psychological problems and relationship problem and it is concluded that mean of psychological problem and relationship problem do not differ significantly across the level of education of respondents.

5. Discussions and Conclusion:

Addiction to social networking is a word that describes someone who spends so much time on various forms of social media that it interferes with other elements of their everyday lives. Addiction generally refers to compulsive behavior which results in negative effects. The present study has been taken up with the aim to identify the internet uses pattern nature of use and internet addiction among the students and assess the impact of internet addiction and its consequences among students. The quantity of time spent on the internet by an individual is a significant element that raises the risk of internet addiction. The study result reveals a linear relationship between internet use and internet addiction. In the study, it was found that the severity levels of internet addiction increase with increased use of the internet (Asiri et al., 2013; Derya et al., 2019; Ceyhan et al., 2007; Chou and Hsiao, 2000; Salehi et al., 2014; Boonvisudhi and Kuladee, 2020; Anand et al., 2017). As a result of the research, it appears that the danger of being addicted to the internet increases as the number of time kids spend on the internet increases. The study indicated that overall excessive use of the internet is more in females (2.9253) than the male students (2.7724) similarly is found that internet addiction is found to be more in female students (2.89) than males (2.7524). The overall prevalence of internet addiction (moderate) is consistent with most research that used Young's IAT to assess

internet addiction. Additionally, a study found substantial disparities between gender categories, age groups, and UG and PG students in terms of internet addiction and overuse, supporting findings from other studies (Goel et al., 2013; Anderson, 2001). The prevalence of internet addiction was found to be and it was significantly correlated with factors like gender, father's occupation, mother's education, availability of personal gadgets, use of a smartphone, and early exposure to the internet. With an increase in internet addiction, there was a subsequent increase in the level of depression, anxiety, and stress (Sharma et al., 2018).

Result of the study indicated that majority of the student uses the internet more than 4 hours daily. The ANOVA result was found that mean uses of the internet differ significantly ($F=2151.630$, $p=0.000$) in the level of internet addiction. Further regression analysis confirms that internet overuses significantly influence internet addiction among students ($\beta=0.978$, $R^2=0.992$, $F= 82521.042$, $P=.000$). Internet addiction was also linked to physical, psychological, behavioral, and relational concerns among the students in this study. Several studies have revealed that internet addiction is linked to loneliness, depression, anxiety, stress, low self-esteem, and life satisfaction, which is consistent with the findings (Kraut et al., 1998; Ko et al., 2005a,b; Panicker and Sachdev, 2014). Additionally, it has been discovered that hooked students are more likely to experience poor psychological wellbeing, which is a comparable result. These findings are consistent with prior research that has found a strong link between psychiatric symptoms and internet addiction (Alavi et al., 2011).

Table 10 The Summary of Hypothesis Testing

Hypothesis		Remarks
H1	Internet uses and internet addiction across the age, gender categories, and level of education of respondents.	Supported
H2	The impact on Internet addiction among the students.	Supported
H3a	The physical problem of internet uses across the gender categories of respondents.	Not Supported
H3b	The psychological problem of internet uses across the gender categories of respondents.	Not Supported
H3c	The behavioural problem of internet uses across the gender categories of respondents.	Supported
H3d	The relationship problem of internet uses across the gender categories of respondents.	Supported
H4a	The physical problem of internet uses across the level of education of respondents.	Not Supported
H4b	The psychological problem of internet uses across the level of education of respondents	Supported
H4c	The behavioural problem of internet uses across the level of education of respondents.	Not Supported
H4d	The relationship problem of internet uses across the level of education of respondents.	Supported

Despite the fact that internet technology is regarded as the most powerful instrument and that people are compelled to use it for a variety of purposes, each person should be able to recognize when the internet begins to take over one's life and obstructs other every day activities. Internet addiction appears to be a serious developing mental health condition among students at all levels of UG and PG in India. Psychological distress (depressive symptoms) and addiction to the Internet have been positively linked and this is a predictor associated with IA. There is a high likelihood that psychological discomfort and IA will coexist and increase one another in engineering students, hence it is important to screen them for both. The beginning of these activities would aid in offering early recommendations to expert facilities for accurate diagnosis and care. Raising students' and faculty members' understanding of IA and its risk factors would thus be a helpful first step towards safe internet use. Future studies will examine the connection between IA and depressive symptoms in a hypothetical setting.

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Appendix A: Abbreviations
(Complete Explanations of the Abbreviations used in this Study)

IAD	Internet Addiction Disorder
PIU	Problematic Internet Use
CIU	Compulsive Internet Use
WHO	World Health Organization
UK	United Kingdom
CD	Compact Disk
IAT	Internet Addiction Test
UG	Under Graduate
PG	Post Graduate
ANOVA	Analysis of Variance
SPSS	Statistical Package for the Social Sciences
SD	Standard Deviation
df	Degree of Freedom
MUD	Multiple Users Dungeons
CIO	Causes of Internet Overuses
IOU	Internet Overuses
PHP	Physical Problems
PSP	Psychological Problems
BP	Behavioral Problems
RP	Relationship Problems

Indian Festivals and Nature Conservation: Connecting People for Sustainability

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Abstract

Purpose-*Today we are witnessing an increasing consciousness among people across the globe concerning the importance of the conservation of nature. The pledge in the direction of the environmental conservation and preservation of nature is gradually developing in various countries. Several festivals in India symbolize a profound connection between people and nature. Keeping this in view, this current study attempts to analyse the role and importance of festivals in India towards the conservation of nature.*

Methodology*-The study undertakes a conceptual approach in order to fulfil the purpose of the study. The secondary sources like articles, weblinks, research papers, reports, etc. have been analysed to obtain the required information and data. Other than that, the available research publications on Indian festivals and their linkages towards nature conservation have been studied in-depth to attain valuable insights.*

Findings-*The findings of the study show that most of the Indian festivals are focused on the celebration of mother nature. In fact, the respect of nature in India is an old traditional practice. Such age-old practices are based on the considerations that nature is the source of everything around us and supports our lives.*

Originality/Value*-In spite of strong linkages between nature and various festivals in India, the awareness and enthusiasm of many people towards the importance of nature conservation is strangely less. The need of the hour is to create awareness amongst people across the globe regarding the real significance of India's traditions with regards to the conservation of nature.*

Keywords: Indian Festivals, Nature, Nature Conservation, Environmental Preservation.

1. Introduction

The Indian civilization is considered to be 4500 years old and culture is one of the oldest cultures in the world. This civilization flourished between 2,500 BCE and 1900 BCE (Wright, 2009). Unity and diversity are not merely the words used to describe the Indian culture but they in fact highlight the reality of its unbelievable rich culture and heritage. India has gone through various phases from the Vedic era to Mauryas, Mughal rule, and British rules. India

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has always been a renowned and popular destination for its cultural diversity and generosity. Indian culture values love, family, relations, and ecstasy in various kinds of celebrations position it as a unique country in the global society. The diversity and hospitality of India attract millions of travellers and tourists to the country. The major purpose behind visiting India is to experience the vivacious and rich culture which is a unification of age-old traditions, religions, norms, food, festivals, arts, handicrafts, traditional music, dances, and many more ingredients. The travellers get mesmerized while visiting India and they highly appreciate the vibrant and unique cultures, values, customs, ceremonies and ethnicities of the country.

Like many other countries, the native people of India believe in the existence of supernatural powers in the sun, moon, planets, trees, animals, plants, mountains, rivers, sea, wind, and fire. In many religions in India respect for nature is inherent. Many gods and goddesses in the Hindu religion are associated with animals and elements. Sacred forests have been part of Buddhist and Hindu culture. Moreover, in religions like Christianity and Islam, a basic principle that exists is that nature is created by God, and humans must preserve and conserve the environment around us. Therefore, being a secular country, India encompasses various ethical and religious viewpoints that focus on the human obligation to care for mother nature.

According to Getz (2008), today's festivals are considered "the most energetic, exciting and vibrant forms of phenomena related to recreation, business, and tourism'. Although they aim to consider favourable impacts of social and economic on the indigenous community in which they operate, that has studied through numerous academics, the adverse environmental effects of these types of events received significantly less focus. (Collins, Langen & Garcia, 2009; Raj & Musgrave, 2010). That is why Getz (2008) seeks for concern about the environmental results of festivals and events which makes this a research priority. In earlier studies, some authors have begun to explore the new field of research. Emphasis on setting up green events and the organizers' encouragement behind greening efforts, still much more needs to be done (Getz & Anderson, 2008, Mair & Laing, 2012; Laing & Frost, 2010; Raj & Musgrave, 2009). With this in mind, the present study seeks to analyze the role and prominence of festivals in India for nature conservation.

Material related to India's festivals, festival impulses were collected from diverse sources such as professional & academic literature, media, web, and many more. The study brings forward the idea that India's culture influences, raise awareness, and sensitizes people to protect the environment through festivities. In several parts of India Native communities have successfully sustained the tradition of preserving nature. In today's world, where environmental degradation and disruptions are a crucial challenge, it is important to understand such ancient traditions and their implications. The research question which this study aims to answer is that how can the Indian festivals contribute towards the awareness and conservation of the nature.

2. Theoretical Background

Events and Sustainability

While there is relatively little literature and studies on environmental, and sustainability matters associated with festivals, there are a few that appear to be quite important for this research in terms of establishing the groundwork for additional investigation. To begin, it is vital to comprehend the many phrases used in the study in relation to concerns elevated regarding the misuse of our environment in the pursuance of economic activities. Terms like 'greening,' 'eco-friendly,' 'corporate social responsibility,' and 'environmentally friendly,' According to Henderson (2011), are interchangeably combined with sustainable, making it impossible to concentrate on one precise concept. Sustainability entails a connection to ecological impacts, such as the consumption of natural endowments and considerations of pollution and energy use, together with the concerns about social inclusion and wealth distribution, as well as economic themes of growth and longevity Musgrave and Raj (2009). The negative impacts of festivals or events create harm for society by polluting natural resources and which cause natural disasters too. Further, these big event celebration results in the health of the local community through air pollution, water pollution, and noise pollution. Natural disasters can have a life-altering impact on the individuals and families fortunate enough to survive them. But the effect of natural disasters can be felt at the community, city, and state level, or many times can impact an entire country. Natural disasters can have huge environmental impacts as well, even when human communities are relatively unaffected. In this respect, it refers to an imperishable, balanced method to commercial activities, environmental stewardship, and social growth and it is applicable to the complete life span and event organization of every main event activity in the event industry. The triple bottom line which includes three important pillars of sustainability are considered very important in organizations. The triple bottom line "reflects an expanding range of principles and standards for evaluating corporate and organizational growth by considering all ethical and social norms that provide benefits to the localities by maintaining their resources more sustainable (Gallagher & Pike, 2011)This indicates that while taking a larger perspective of corporate behaviour, from merely concerned with profit to only which involves people and plants too. Meanwhile, Henderson (2011) points out that many of the above terms (such as greening) today emphasize the 'planetary' or "human" aspect of sustainable development, thereby these conventions Is too simple. He argues those who want to manage the activities in a sustainable way should consider all the three elements of sustainable development. The term 'green event' could be determined as an affair that includes fair policies by either containing sustainable activities into the administration actions and functions & which claim as well that green events frequently have bigger attention than its direct environmental implications. Henderson (2011) enhances this via way of means of announcing that a service industry-like occasions administration would be properly exhorted to require a more extensive opinion of its sustainable development enveloping each the 'product' the 'process' perspectives. In lots of methods, fairs constitute the microcosm of the worldwide problems referring to ambient

useful resources and management since they consume resources from the environment along with this generate waste and result in the transmission of pollution in the natural environment

Gallagher and Pike (2011). Jones (2010) additionally claims about 'going green' manner greater than about the carbon footprint and a few light-weight actions. She too claims about more extensive view should be taken, counting maintainability and conventional natural regards; asset utilize is especially pertinent to occasions. The difficulty in favour of events thus goes on the far side alone applying and financing in green practices and facilities. The measurements of sustainability for occasions and as well as tourism are characterized by its association with the common assets; with the political support and the local community; with financial matters and demand; and with operational administration (Getz and Andersson, 2008; Moscardo, 2007). It is hence the more extensive administration and decisions should be taken at the common ground by including all stakeholders while organizing any event. Musgrave & Raj (2009) gave a conceptual system for sustainable occasions that gives a presentation to the basics of sustainability, consistency, and integration inside the occasion's procedure. Ten principles that represent the fundamental reasoning by the way sustainable occasions ought to symbolize a vision and general heading, which must be approachable and reasonable. Buizer (2009) recognizes a developing awareness of how we use our natural resources and deal with it. Dutch segment contends that a few celebrations have been investigating the conceivable usage of Corporate Social Responsibility (CSR). A further examination in the direction of greening among the Dutch music festival sector thus appears to be appropriate against both academic and societal purposes. This research primarily focuses on the motivations, obstacles and findings of greening practices and can thereby be considered as a follow-up of research executed by Mair & Laing (2012), which is now applied to a diverse spatial context.

Originally, many countries across the globe have rich traditions and ethics of protecting nature. Various ancient cultures tell stories of how communities lived in harmony with nature in old times, with a tradition of respecting elements that create our ecosystems. As we look toward environmental conservationism in the India context, it is vital to recognize the fact that the viewpoints of western world do not automatically apply in the South Asia (Christopher K. Chapple, 1998; Gotham, 2002). According to O. P. Dwivedi (2004) in the ancient India, Hindus and Buddhists were devoted towards moral traditions concerning the dealing with nature. In both Hindu and Buddhist cultures, the common people as well as the rulers followed such traditions and norms in order to create awareness among masses. Hindu and Buddhist traditions can play a vital role in solving various environmental problems being faced by India and other countries in South East Asia (David Gosling, 2001). Eco-friendly ethics in Buddhism present logical dimensions and ways of interactions with the nature. The meaning of nature in the early Buddhist context have roots to the teachings on dhamma, cosmogony, samsara and therefore we can say that environmental virtue ethics are inherent in Buddhism (Pragati Sahni, 2007). Unfortunately, in the current times the modern people look down on native

people as superstitious and backward. But these people have a deep understanding of nature, and ways to that sustain the ecosystems. In the words of Greeti Sen, ed., (1992), Indian people worship trees and nature not just because the people are sensitive towards environmental protection, but also due to the reason that these traditions and practices are old and passed on through generations as a way of life. In addition to this, numerous people in India, are directly reliant upon the nature for agricultural practices and food requirements and they simply cannot pay the price for changing their behaviour for nature to accommodate environmentalist goals (Barlow and Shibli, 2007; Getz, 2010; Emma Tomalin, 2002; Tang and Turco, 2001).

Organizing various festivals and celebrations is deeply inherent in culture of India. The Hindu literature, scriptures and text refer towards celebrations of various festivals throughout the year. Many of these festivals are way to show respect Gods associated with nature including, mountains, rivers, trees, seasons etc. Such festivals are performed not only by praying individually or with family but are also celebrated in the form of in socio-cultural events. The culture of conservation of nature originates from the ancient Vedic texts namely, Rig-Veda, Sama-Veda, Yajur-Veda and Atharva Veda. These Hindu texts are devoted to the power and appreciation of nature and living beings. These texts refer to various gods and goddesses linked with rivers, mountains, sun, moon, thunder, rain, trees etc. Enabling sustainable associations amongst individuals and nature is one of the most crucial and urgent environmental and social problems of this era. R. Narayan and J. Kumar (2003) mentioned that various religious literature and scriptures speak about the end of the world. Slowly, with the problem of disruptions of ecology, people are getting concerned about the end-game. Therefore, in current times a religious and traditional approach can be an appropriate way to stimulate human psychology, as it is necessary to draw the attention of man upon the importance of ecology through age-old wisdom.

For the Indian people, conservation of the environment is not a new concept. Factually, the protection of nature and wildlife is linked with the faith of people which reflects in their daily lives, preserved by religion, folklore and culture. The Upanishads (an ancient scriptural text), over 2000 years ago talked about the fundamental ecology, environment, nature, the interrelationships and interdependence of all living beings on earth. This text further mentions that the universe has been created by an ultimate power and the universe is created for well-being of all the living beings. Further, each living being must, live in harmony with the other species by forming a system of relationships for mutual benefits. K.D. Upadhyaya (1965) explained that the Aryan race in India has been worshiping trees for centuries and nature plays a significant part in their daily lives. The history India is full of customs and traditions which highlight the importance of nature in our lives.

Case Study of Indian Festivals

Loudspeakers, fire crackers and loud musical instruments, appear to be one of the biggest culprits of noise pollution during festivals in our country. With the advent of urbanisation, people in the metros had to grapple with the problem of noise pollution in everyday living, and any kind of public celebration only aggravates this lurking issue. A study by World Health Organisation (WHO) asserts that noise pollution is not only a nuisance to the environment but it also poses considerable threat to public health. Divali one of the imperative celebrations in India has the refinement of contaminating the environment to the core. Newborns and elderly people have an awful encounter because of the high sound caused by wafers amid Deepavali. Commotion contamination on Deepavali is between 69.7 d and 88.3 dB which are greater than the endorsed constrain of 50db. The decibel levels are alarmingly above in metros and it may reach up to 100 dB Environmental groups and eco-clubs are clearly fighting a defeat. They devised awareness campaigns and slogans like "Deepavali could be a celebration of lights, not wafers, celebrate an eco-sensitive Deepavali this year", but no one appears to require to take note. Other than the noise wafers, release a high amount of toxic gases like Nitrogen dioxide and Sulfur dioxide which can direct to numerous health problems. Apart from releasing toxic gases, bursting of crackers also leads to pollution of air. Diwali, every year leads to an alarming rise in the level of Respirable Suspended Particulate Material (RSPM) in the air, due to bursting of fire crackers. RSPM are minute particles and can contribute to various health issues including asthma and bronchitis. Chemicals used in crackers like nitrate, sodium, lead, magnesium, cadmium, and others can have different destructive impacts (Singh, 2015) Press Trust of India (October 31, 2016). Deepavali firecrackers pushed contamination in Delhi to a perilous level, the most exceedingly bad in three years, because it turned the air exceedingly poisonous due to a dangerous cocktail of destructive respirable poisons and gasses, immersing the city with a cover of thick exhaust cloud activating wellbeing alerts. Different monitoring organizations counting Delhi Pollution Control Committee (DPCC), Central Pollution Control Board, Pune-based SAFAR, and the Centre for Science and Environment were consistent with almost the seriousness of the air quality within the city (India, 2016). Adit Suneja composed a commentary entitled 'Environment and Modernity in 2009. Right from celebrations to holiday trips to party celebrations our activities disturb the balance in nature. Beginning with the festivals numerous of them include submerging sacrosanct statues in streams, rivers, or seas causing water contamination. Water bodies have self-drawing capacity, but it contaminated beyond the immersion point, they aggravate the oceanic life. Numerous assortments of fishes are known to have ended up imperilled due to our negligence.

A few celebrations include impacting wafers which causes air contamination. Not as it were this, stray animals endure severe trauma since of the intolerable commotion of wafers (Suneja, 2009) Press Trust of India reports (2012) separated from all the fun and social judgment, the Ganesha celebration moreover has some terrible effect on the environment. According to tradition, on the final day of celebration, all the idols are inundated within the nearby lakes or

rivers. It causes the pollution of these significant water resources. Plaster of Paris and paint with dangerous chemical colours are used to make idols which are contaminating the water bodies. Alongside idols, there are various non-biodegradable accessories used throughout the worship that is additionally immersed in the aquatic environment. In major cities like Mumbai, Pune, Hyderabad, etc. where commercialization has taken these festivals and celebrations to another level; the contamination caused by the aficionados is on an awfully huge scale. Hussain Sagar Lake found in Hyderabad city where the Ganesha celebration is celebrated on the little scale compared to big cities in Maharashtra state; more than 5000 Ganesha idols are drenched in this as it were one lake (Indian Today, Oct. 6, 2012). The situation of all the waste within the lakes on another day after the immersion ceremony is truly bad.

Fowler Smith (2009) argued that our perception and contemplation of nature, ultimately affects how we treat the nature around us and how we interact with it. In the religious context, the trees are perceived as life-givers. The practice of worshipping the trees by decorating, organizing festivals linked with them, and protecting them has been an age-old culture in India. The trees are looked upon as living beings that are sacred and therefore are protected by people. The Indian paintings, architecture, folklore, sculpture, ornaments, and handicrafts are often influenced by nature and wildlife reflecting the sense of love and appreciation for nature. A diverse range of forests, plants, and animals can be found in Indian sculptures, crafts, and miniature paintings. Moreover, the Hindu God Krishna's life which is depicted in the form of paintings often represents the appreciation for nature and the importance of ecological balance. Looking upon history, Hinduism is the oldest noticeable civilized culture in the Indian subcontinent. Although, interpretations and associations of this religion with worshipping of trees, water bodies, nature, and animals can vary across the country, but it's definitely deep-rooted in the conscience of the people of India (Elgood, 2000).

3. Research Mythology

The study undertakes a conceptual approach in order to fulfil the purpose of the study. Conceptual research is defined as a methodology wherein research is conducted by observing and analysing already present information on a given topic. Conceptual research doesn't involve conducting any practical experiments. It is related to abstract concepts or ideas. Philosophers have long used conceptual research to develop new theories or interpret existing theories in a different light. Therefore, for this study utilizes secondary sources like articles, weblinks, research papers, reports, etc. in order to obtain the required information and data. Other than that, the available research publications on Indian festivals and their linkages towards nature conservation have been studied in-depth to attain valuable insights.

4. Findings and Discussion

Several Indian festivals symbolize a deep link amongst man and nature. If we try to observe and understand the significance of the several Indian festivals, it becomes clear that that majority of these festivals celebrate mother nature and her blessings. It's quite clear that the

reverence of nature in India is an age-old practice. Such traditional practices of worshiping and protecting nature arise from the thought that the humans owe it to the nature for our well-being. Therefore, it can be said that in India, nature is worshipped as well as conserved in India.

In India, one can often come across people worshipping some specific trees and plants which have religious and scientific importance. For instance, Vat Vriksha Puja (a prayer ritual performed by Hindus) is an Indian festival in which devotees walk around a Banyan tree while offering water and other offerings. The puja is performed because of age-old traditions, but at the same time Banyan trees also have scientific importance and hence are valued by people. Another such festival is Chaath Puja Festival, which is a festival to show gratefulness towards Surya (Sun God). This festival and the underlying rituals are specially performed on banks of rivers and other water bodies. The rituals under this festival are performed by taking dips in the water and offering flowers to the river, which symbolizes the importance of water in everyday life (Subhamoy Das, 2015). Similarly, Kua Pujan is another custom of worshipping well, which are water bodies used by people in rural areas for drinking water. This is performed on the occasions of child birth and marriage ceremonies. Makara Sankranti, is another Indian festival, dedicated to the sun god Surya. This festival is celebrated every year in the lunar month corresponding with the month of January. On this day people in India also celebrate their crop harvest (James G. Lochtefeld, 2002).

The Hornbill Festival, which is organized at Naga Heritage Village in Nagaland, is an significant environment and nature associated tribal festival in India (Jaini, Kshaunish, 2017). This festival is celebrated in the month of December and is named after the Hornbill bird which has lots of relevance and importance in the cultural and folklore of the Naga tribes. This festival spreads the global message of conservation of environment and reviving also defending the cultural heritage. Another similar festival is, Manipur Sangai Festival which is named after Sangai (Manipur's state Animal), a rare brown deer found in Manipur's Keibul Lamjao National Park. This festival aims at sensitising people about protection of nature and also showcasing the local indigenous dances like Raas Leela, martial arts, crafts and culture. Another week-long festival for planting trees and rejoicing the importance of forests is organised by the Indian government which is known as Van Mahotsav, or the festival of forests. Citizens of every state are also as encouraged by the government to participate in planting trees across the country. Van Mahotsav, generally celebrated in the first week of July across the country and includes several little events in societies, schools, organizations and neighbourhoods where people come together to debate about protection of nature, plant trees and create awareness among masses. Pushkaram is an Indian festival devoted towards paying respect to rivers. This festival is celebrated at various shrines located on the banks of 12 sacred rivers in India. The festival includes rituals and activities praying, chanting, musical performances, religious performances and cultural programmes. This celebration occurs only once in 12 years. (Roshen Dalal, 2014). Harela (green) festival is organized in the state of Uttarakhand. This traditional festival marks

the beginning of rainy season. Harela festival is celebrated during the beginning of the month of July across the Kumaon region in Uttarakhand. This community-based festival specifically celebrates rain as it is important for the local farmers (Ramesh Chandra Bisht, 2008).

Hence, it is significant to understand that nature is revered and worshipped in India to recognize the power of nature and the blessings it provides to the people. The various festivals which are organized in order to celebrate nature and to worship it, also signify in a very noticeable and refined manner that there is need to preserve nature. The belief behind these customs of Indian people is that 'we don't destroy that which we worship'. Therefore, festivals in which nature is worshipped are continuous cues for people that there is need to conserve nature from mistreatment and annihilation. Considering this, it is safe to state that that various indigenous Indian festivals are directly or indirectly linked with the protection of nature.

5. Conclusion

It won't be erroneous to claim that India's obligation and devotion to conserve nature and its components is deep-rooted in ancient traditions. In other words, it can be said that India's commitment towards nature and its conservation is an image of India's thousands of years old culture and it has the potential to spread above and beyond international borders or across the globe. The apprehension and commitment towards nature is an inherited part and promise of numerous indigenous festivals of India. Today the need of the hour is to create awareness within people across the world regarding the significance of India's age-old traditions regarding conservation and protection of nature. Fascinatingly the general outlook of Indians towards nature and their comprehension of various environmental topics are deeply rooted in the religion and culture. And such outlook can be channelled to create a sense of connection with nature amongst new generation. Moreover, India also needs to renew its strategies of nature conservation and adopt advanced knowledge systems to hold the society together. The new strategies should be grounded, resourceful, effective, sustainable and supported by a belief system based on admiration and respect for the natural resources of the country.

6. Research Implications

Considering the scarcity of conducted investigation with respect to sustainability and events, still a gap remains to be explored. Foremost, it may be important to confirm the finding from this study, by applying quantitative techniques at large scale in future studies to have more insights in context of sustainability and events. Future studies can also conduct research by considering the relationship among the determinants and barriers of sustainable events. It is supposable that pop festivals are much more concerned with its impact on the environment than the dance festival Another component that needs further examination, is the kinship between the framework of organization to prepare for the festival along with the way in which sustainability is at utmost priority. Since there are not as it were contrasts between the festivals itself, but too between the associations that organize them, it might be curiously to investigate how this relates to the sustainable results of a festival. Future researchers can also incorporate both qualitative and quantitative approach in their study and can bring more wide results.

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A Green Supplier Selection Model for Computer Accessories Manufacturing Organization under Uncertain Environment

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Abstract

The necessity of including environmental concerns in business operations like supplier selection is rapidly gaining importance in various companies. Firms are taking interest in incorporating green practices in their supply chain management operations to enhance the green image and to abide by the environmental regulations. In this study, a case of computer accessories manufacturing company in India is chosen. The case company considered in this study is in exigency of choosing the most optimal green supplier to complement its recently implemented green strategies. Therefore, this work proposes a green supplier selection model based on Fuzzy VIKOR method. A set of criteria was developed based on the literature review and in consultation with stakeholders of the company. Then, the fuzzy VIKOR methodology was utilized to evaluate the green practices of the supplier. The significance of the selected MCDM approaches in the case company has been demonstrated and it is confirmed that the outcome of the study assists the company in establishing a systematic approach to choose the most optimal green supplier.

Keywords: *Multi-Criteria Decision Making (MCDM); Green Supplier Selection; Fuzzy VIKOR; Environmental Management Systems (EMS).*

1. Introduction

In recent years, the significance of GSCM has witnessed a meteoric rise. Due to increasing ecological awareness among consumers and insistence to fulfill environmental protocols by government, companies can no longer neglect environmental concerns in their administrative activities (Porteous et al. 2015, Corbett and Kleindorfer 2001, Letizia & Hendrikse, 2016, Agrawal and Lee 2019, Lee and Klassen 2008, Jiuh-Biing Sheu 2016). Environmental concerns have thus become a key strategic consideration in supply chains (Büyüközkan and Gizem 2012). Mohanty and Prakash, (2014) confirmed that Indian firms are confronting pressure from external shareholders to implement GSCM practices. Besides contributing towards improvement of the environment, application of eco-friendly practices like GSCM also helps

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the companies to gain a competitive edge. Accordingly, companies are striving towards a greener supply chain (Bose and Pal 2012).

The most significant aspect of greening the SC is the choosing of green supplier (Xiong et al., 2013, Kassinis and Soteriou 2003). It is also among the most crucial and complex issues that need to be dealt with by the operations and purchasing managers (Bai and Sarkis, 2010, Bowen et al. 2001). Apart from traditional criteria for selection of suppliers like timely delivery, value for money, etc., the managers also need to include GSCM criteria in their evaluation of potential suppliers. The evaluation models of supplier selection should include environmental concerns if the company wants to enhance its green image and stay ahead of the competition (Hashemi et al., 2015). The prime motivation behind this research work is the rising importance of GSCM practices in the existent industrial scenario. Adopting GSCM practices is becoming increasingly beneficial and necessary in various industries. Vanalle et al, (2017) demonstrated that performances of the supply chain based on economic and environmental factors are positively related in adoption of GSCM practices. Similarly, Geng et al., (2017) reviewed 50 articles on GSCM and discovered that the use of GSCM in the growing economies resulted in a superior economic, operational, environmental, and social performance. In India, due to accelerated worsening of the environment, the government is forcing industries to become greener and reduce their environmental impacts. Bose and Pal, (2012) found that firms announcing their adoption of GSCM practices witnessed a significant gain in their stock prices. This shows that the customers value the endorsement of GSCM practices. Thus in the existent industrial scenario, adopting and implementing GSCM practices has become highly significant.

Although there are studies which utilizes fuzzy concepts for selection of green supplier in a variety of manufacturing sectors, studies regarding green supplier selection for computer accessories manufacturing is nonexistent. However, there exist limited number of literature on green supplier selection using fuzzy VIKOR (Banaeian et al. 2018; Sasikumar and Vimal, 2019) on computer accessories supplier selection problem. Correspondingly, there are literatures that dealt with green supplier selection using methods other than MCDM techniques. Composite indicators (CI) were used to select the supplier considering environmental aspects and using Data Envelopment Analysis (DEA) with the Common Weights Analysis (CWA) method by Dobos et al. (2014). Therefore, there exist a gap in utilizing MCDM approach in green supplier selection on computer accessories in detail. Though a single techniques can be used for the case study, combination of two or more methods addresses drawbacks that are pesent in other methods (Velasquez and Patrick, 2013). In this view, the present research aims to address the following research questions.

RQ1. What are the key criteria specific to selecting green suppliers for computers accessories manufacturing organization?

RQ2. How the priority of the supplier could be identified considering selected criteria to adapt green supply chain management?

In this paper, fuzzy VIKOR techniques is used for the process of selecting the best green supplier because of their simplicity and ability to consider indefinite number of alternatives and criteria in decision-making activity. The research work objective is to determine the optimal green supplier for a computer accessories company in Indian context. To achieve the above objective, a set of related criteria has been established from existing literature review as well as industry input. Primarily, decision maker's preferences were taken in the form of questionnaires to define the significance of criterion, sub-criterion and alternatives rating. Then linguistic preferences were converted to triangular fuzzy numbers. Subsequently, fuzzy VIKOR methodology was applied to get the ranking of the suppliers. The validation of the rankings obtained could be verified by observing the similarity in rankings obtained from the two methods. The later sections review the case study, proposed framework, methodologies used and analysis

The principal purpose of this research is to provide a framework model for selecting suppliers adopting eco-friendly strategies using the systematic and computationally simple fuzzy VIKOR MCDM methodology. Present supplier selection scenario presents various complexities and challenges such as numerous and often conflicting criteria, many alternatives to choose from and uncertainties and fuzziness in the preferences of decision-makers. Fuzzy VIKOR methodologies was used in this research due to their various advantages such as delivering results which are close to ideal, ability to measure the relative performance for each alternative, comprehensibility and wide usage which makes it familiar for organizations and managers over some other MCDM techniques. In this case, 7 main and 26 sub-criteria, 7 potential suppliers and 6 decision makers are considered. These techniques are highly useful in this case as they provide a systematic structure computational simplicity while handling a large number of criteria, alternatives and decision makers. These techniques are also preferred to methodologies such as AHP (Analytical Hierarchy Process) and fuzzy AHP which require pairwise comparison of criteria. These methodologies also provide a numerical value to each alternative which could be used to better understand the differences between alternatives. Thus, the adopted methodologies have an advantage over some other MCDM techniques such as ELECTRE (ELimination and Choice Expressing REality) which only provide the rank of alternative. Thus the MCDM techniques used in this work can efficiently and effectively handle the challenges. Also, managers can easily adopt this framework in their firms for quick and efficient determination of green suppliers.

The rest of the article is organized as follows. Section 2 discusses on literature review about GSCM criteria. A case study of an Indian computer accessories firm is represented in Section 4. In subsequent section MCDM analysis has been conducted to evaluate the potential

suppliers using fuzzy VIKOR method. Results are illustrated in Section 5. In Section 6 conclusion along with future research directions are presented.

2. Literature review

2.1 Green Supply Chain Management (GSCM)

GSCM is an approach in which environmental concerns are included in the supply chain management. (Srivastava, 2007). This includes various aspects of the supply chain like design, manufacturing and delivery of products, material sourcing, etc. the set of environmental friendly practices included in GSCM supports improvements of the same supply chain in an organization. (Vachon and Klassen, 2006). Government and customers want minimum damage to the environment. Thus companies need to become greener (Marcus and Fremeth, 2009), and link sustainable development with supply chain (Seuring, 2013).

Some of the definitions of GSCM are given below

- GSCM, in the context of supply chain management, is the amalgamation of best practices of both organizational and concerns related to the environment. (Sakris et al., 2011).
- GSCM is the consolidation of green resourcing, manufacturing, marketing, packing, and distribution (Jayant and Azhar, 2014).
- GSCM involves consideration of environmental concerns at various stages of operations of the company like purchasing, design and development of the product, packaging, transportation, disposal etc. (Min and Kim, 2012).

2.2 Green Supplier Selection

Selection of green suppliers is becoming increasingly important to various companies. Gunasekaran and Ngai, (2012) stressed on the fact that including environmental considerations in the area of supply chain and operation management is increasingly becoming common. Inclusion of GSCM practices in one tier of supply chain can benefit all the companies included in the supply chain by increasing their environmental performance. The significance of environmental considerations in supplier selection is higher in developing countries due to the obstacles and challenges faced by companies in these areas (Akamp and Müller, 2013).

Organizations that aim to achieve sustainability often give importance to environmental considerations in selecting their suppliers (Dekker et al. 2012). Govindan et al. (2013) made use of triple bottom line concept in selecting the criteria for supplier selection. They stressed on incorporating sustainable supply chain criteria along with traditional supply chain criteria in supplier selection to achieve the triple bottom line in the SC. Due to its significance, many studies on the green supplier selection has been performed. Yazdani et al., (2017) explored the inter-relationships between green supplier selection criteria and customer requirements. This

was done with the help of DEMATEL method and QFD model. Additionally, COPRAS method was used for ranking the alternatives. One of the primary aspects of their research was to incorporate green factors for selection of the suppliers. Even though it is well established that supplier selection criteria are important, development of robust selection methods faces some significant challenges in the process. Igarashi et al., (2013) found various short comings with respect to green supplier selection. This was done by reviewing 60 articles related to its which has been published in peer-reviewed journals. Some of the main findings include - research connecting the selection of green supplier to organizational strategy is lacking and the research on selection of green supplier is very fragmented and often stresses on the technical aspects of selection.

There has been a vast amount of studies in the area of GSCM. Various criteria are used by various authors in their studies. In this study, the criteria used by various authors along with some new criteria which are relevant in this context are consolidated. Some negative (unfavorable) criteria are also included for evaluation of the supplier (e.g. – C5 Use of materials harmful to the environment). A framework model consisting of seven criteria and 26 sub-criteria have been developed for this study based on literature review. The description of the various criteria used and previous authors who have considered the criterion are listed in Table 1.

Table 1 Proposed Criteria for GSCM

Serial number	Criterion	Previous authors who have considered the criterion	Description
C1	Environmental Management systems	Chiou et al. (2008), Humphreys et al. (2006), Grisi et al. (2010),	How effectively the organization uses EMS as a tool to manage the impact of its activities on the environment
SC11	ISO-14001 Certification	Humphreys et al. (2006), Kuo et al. (2010)	ISO-14001 Certification status of the organization
SC12	Regulatory compliance and Continuous monitoring	Lee et al. (2009)	Level of supervisory fulfillment issues and continuous monitoring
SC13	Green process planning	Lee et al. (2009), Chiou et al. (2011),	Green level process planning in the organization
SC14	Eco-labelling	Li Cui (2017)	Presence of eco-label in the products supplied by the organization
C2	Eco-Design	Liu et al. (2010), Kuo et al. (2010), Zhu and Sarkis (2004)	Design of products considering its impact on the environment

SC21	Product design for reduced energy/material consumption	Kannan et al. (2014)	Design of product which uses less energy/material.
SC22	Product design for recycle, reuse, materials recovery, component parts	Kannan et al. (2014)	Product recycle design, reuse, recovery of materials, component parts is easily possible
SC23	Product design for eco-friendly disposal	Kannan et al. (2014)	Design of product which could be easily disposed in an eco-friendly manner
SC24	Product design that uses eco-friendly materials instead of hazardous materials	Kannan et al. (2014)	Design of product which uses eco-friendly materials instead of hazardous and toxic materials
C3	Investment Recovery	Zhu and Sarkis (2004), Zsidisin and Siferd (1998)	Value recoverable from end-of-life products
SC31	Selling of excess inventory/materials	Rostamzadeh et al. (2015)	Selling of excess inventory/materials which are currently not required
SC32	Selling of used materials and scrap	Kannan et al. (2014), Zhu et al. (2010)	Selling of used materials and scrap
SC33	Selling of excess/obsolete equipment	Zhu et al. (2010)	Selling of old or excess equipment which are not required
C4	Costs incurred	Ayağ and Özdemir (2006)	Costs related with procuring the product from the organization
SC41	Purchasing price	Ishizaka (2014)	Costs of purchasing the product from the organization
SC42	Cost of component disposal	Pochampally and Gupta (2004)	Cost of disposal of components
SC43	Resources and energy consumption	Grisi et al. (2010)	Resources and energy consumed by the organization
SC44	Carbon Credit	Hsu et al. (2013)	Carbon credit of the organization
SC45	Engineering Overhead costs	Jiang and Chi-Hsing (2001)	Costs involved in Engineering Overhead
C5	Use of materials harmful to the environment	Lee et al. (2009), Liu et al. (2010)	Toxic and hazardous resources usage for making the product
SC51	Ozone depleting substances	Handfield et al. (2002), Kuo et al. (2010)	Use of substances affecting ozone layers such as CFS's for making and distributing the product

SC52	Toxic materials usage	Chiou et al. (2008), Azevedo et al. (2011)	Use of toxic materials affecting the environment for making the product and distributing the product
SC53	Hazardous waste generation (per unit of product)	Tseng and Chiu (2012)	Total number of Hazardous waste generated per product per year through activities that involve industrial and other ways of wat generation
C6	Current environmental impact	Grisi et al. (2010)	Current impact of the organization to the environment
SC61	Air pollutants emission	Humphreys et al. (2006), Yang and Wu (2008), Lee et al. (2009)	Current air pollutants emission by the organization
SC62	Sewer discharge	Grisi et al. (2010)	Current sewer discharge by the organization
SC63	Solid waste production	Yang and Wu (2008), Lee et al. (2009)	Current solid waste production by the organization
SC64	Power consumption	Grisi et al. (2010)	Current power consumption by the organization
C7	Alliance with suppliers and customers for greener and cleaner production	Vachon and Klassen (2008, 2006), Diabat and Govindan (2011), Large and Thomsen (2011), Azevedo et al. (2011),	Suppliers and customers collaboration for cleaner, greener production
SC71	Environmental friendly packaging	Chiou et al. (2008), Buyukozkan and Cifci (2011)	Use of packaging which isn't harmful to the environment
SC72	Reverse logistics	Handfield et al. (2002), Chiou et al. (2008)	Level of reverse logistics done by the organization
SC73	Eco-friendly technologies	Patra and Purnendu (2018),	Use of technology which isn't harmful to the environment

2.3 Application of Multi Criteria Decision Making in Selecting Suppliers Adopting Green Strategies

An extensive literature review was conducted to identify the relevant sub criteria and criteria that needs to be taken into consideration of selecting the suppliers adopting green strategies and various MCDM processes that are currently being used for green supplier selection are also analyzed. For example, Hamdan and Cheaitou (2016), Raut et al. (2020), Mohammed et al. (2019), Wang et al. (2019), A Jain et al. (2020) and N Jain et al. (2020) used AHP and Fuzzy TOPSIS technique for selection of supplier and order allocation. Gustibna et al. (2020) projected a fuzzy axiomatic design method for the selection of green suppliers in Textile

Industry. Buyukozkan and Cifci (2011) and Phochanikorn and Tan (2019) used hybrid fuzzy ANP model to assess the suppliers. Numerous studies use MCDM in the process of selection of green supplier. AHP and fuzzy AHP method are widely used in supplier selection researchers (Lee et al. 2009, Shaw et al, 2012; Sivakumar et al, 2015)). A brief description of some of the studies in green supplier selection using MCDM techniques is given in Table 2. The results of the literature review, Fuzzy VIKOR and Fuzzy TOPSIS approach were used in selecting the suppliers adopting green strategies.

2.4 Need for Studying Supply Chain Related to Computer Accessories

With meteoric rise in environmental concerns over the past decade, a concord is growing that environmental pollution concerns accompanied by rapid industrial development should be tackled together with supply chain management, thus contributing to green supply chain management (Sheu et al. 2005). Since the Restriction of Hazardous Substances directive (RoHS), Waste Electrical and Electronic Equipment directive (WEEE), Eco-design for Energy using Products directive (EuP) and other significant directives were enforced by the several influential countries, GSCM has been adopted as a proactive strategy by leading computer accessories companies to reduce their carbon foot print and E–waste. In order to select the proper supplier, the manufacturing company should take into account of crucial factors which permits them to achieve their goal. This can be done by choosing proper criteria that aligns along with their goal. The SC11 (ISO-14001) is an internationally accepted standard for C1 – Environmental Management systems that helps the computer accessories manufacturer to efficiently distinguish between the suppliers. SC23 (Product Design for ecofriendly disposal) ensures that the designed product from the supplier doesn't cause any harm to the environment (C2 Eco Design) and reduces their E-waste.

Table 2 Application of Multi Criteria Decision Making in Selecting Suppliers Adopting Green Strategies

Sl. No.	Author	MCDM Methods Used
1	Hamdan and Cheaitou (2016); Raut et al. (2020); Mohammed et al. (2019); Wang et al. (2019); A Jain et al. (2020); N Jain et al. (2020)	AHP, fuzzy TOPSIS
2	Qin et al (2017)	Extended TODIM
3	Galankashi et al. (2015)	NGT, Fuzzy ANP
4	Büyüközkan and Çifçi (2011); Phochanikorn and Tan (2019)	Fuzzy ANP
5	Pourjavad and shahin (2020); Buyukozkan and Cifci (2012)	Fuzzy DEMATEL/TOPSIS
6	Kuo et al. (2010)	Hybrid ANN/DEA/ANP method
7	Gustina et al. (2020)	Fuzzy Axiomatic Design (FAD)

8	Galankashi et al. (2015)	ANP with improved GRA
9	Dey et al. (2013); Ecer (2020); Deshmukh and Vasudevan (2019)	AHP
10	Qu et al. (2020)	ELECTRE, Fuzzy TOPSIS

3. Method

3.1 Problem Background

The case organization is located in Chennai, Tamil Nadu, India. The case organization is involved in manufacturing of computer accessories (hereafter referred to as ABC). The case study for this research was taken from a major Indian computer accessories company ABC. The organization is an ISO 9001:2000, ISO14001 certified company performing green practices in its activities. The organization aims to renovate its supply chain by opting best green supplier. Almost 700 employees work here per shift primarily assembling electronic products. The company has applied modifications to the assembly and manufacturing of its products. These modifications were made for compliance with the environmental regulations as well as to tackle the rising demand. Some of the other benefits from these modifications include recyclable, lightweight product, free of toxic materials and considerably lower electricity usage. Furthermore, life cycle assessment is also carried out by the company. LCA is useful for evaluating resource usage (such as raw material consumption) and implementing reduction practices (such as reducing waste missions). In the context of these eco-friendly alterations, the chief sustainability officer needed a way of finding the suppliers who can support and strengthen the GSCM practices that the company follows. Seven prospective suppliers have been recognized by the company. Among the chosen prospective suppliers few companies employ various measure to reduce their carbon foot print and to increase their sustainability. All the chosen suppliers are pioneers in their field, including various process such as silicon extraction, silicon wafer production and transistor production. Extensive interviews and brainstorming sessions were carried out with the executives of the case organization to understand their need regarding supplier selection, methods and data collection. Data was collected by forming a cross-functional team consists of stakeholders across the organization and with experience of more than eight years in the case organization. Questionnaires, reflecting the companys objectives were prepared and given to six decision makers. These decision makers have an average experience of greater than 8 years, possessing expertise in the field of GSCM, provided their preferences regarding the significance of criteria and rating of alternatives vis-à-vis criteria. This was then utilized for choosing the most optimal green supplier. In Figure 1, the hierarchy of the methodology adopted is illustrated. From the Figure1 it can be infered that in order to select the best green supplier 7 criteria are chosen which is immediately followed by number of sub-criteria. The 7 prospective suppliers are lined below are ranked with the help of weights of criteria and sub-criteria.

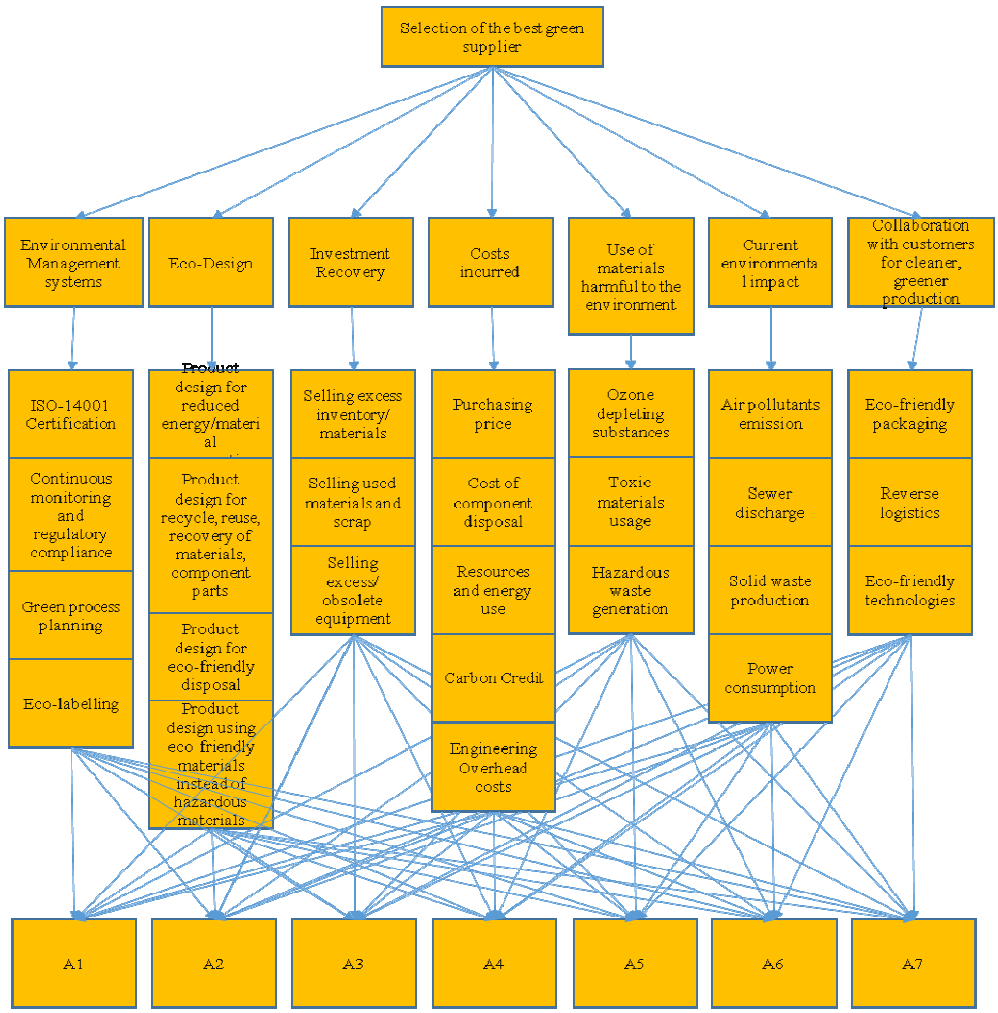

Figure 1 Hierarchy of the Problem

3.2 Fuzzy Set Theory

Crisp values are often inadequate to represent the real world problems due to the imprecision, vagueness and thinking in a subjective nature (Shen et al., 2013, Chiu and Hseieh, 2016). Therefore, metrics involving human reasoning and judgements like preferences and performance ratings of suppliers can be better handled by fuzzy numbers using the fuzzy set theory. The concept of fuzzy set theory to mathematically resolve uncertainties due to human judgment and cognition was first developed by Zadeh, (1965) and Zadeh, (1976). Fuzzy sets were first used in decision making by Bellman and Zadeh, (1970). Fuzzy Multi Criteria Decision Making (FMCDM) is being used by various researchers in solving various problems that involve decision making like ranking airline carriers (Torlak et al., 2011), risk assessment in construction projects (Taylan et al., 2014), etc.

In this paper a model for selection of green supplier for a computer accessories industry in India is developed using fuzzy set theory. This is solved as a FMCDM problem in which the

attributes such as preferences of criteria and alternatives are given by the executives. The attributes are taken in the form of linguistic variables and then converted to Triangular Fuzzy Numbers (TFN) for further computation. Triangular fuzzy numbers are exercised for two reasons, its simplicity in computation (Kannan et al., 2009) and its effectiveness in problem that involve decision making with imprecise and subjective information.

Definition 1: *Fuzzy set* - Let the field of study be represented by Z, $Z=\{z_1,z_2 , \ldots ,z_n\}$.A set of order pairs $\{(z_1, f_B(z_1)), (b_2, f_B(z_2)), \ldots ,(z_n, f_B(z_n))\}$ is fuzzy set (B) of Z, where $f_B: Z\rightarrow [0,1]$ is the membership function of B, and $f_B(z_i)$ denotes the membership degree of z_i in A.

Definition 2: *Triangular fuzzy number* - A triangular fuzzy number is denoted using a trio (t_1, t_2, t_3). Fig. 2 presents the associate function of the fuzzy number $f_B(z)$ and is represented as:

$$f_B(z) = \begin{cases} 0, z < t_1, z > t_3 \\ \frac{z-t_1}{t_2-t_1}, t_1 \le z \le t_2 \\ \frac{t_3-x}{t_3-t_2}, t_2 \le z \le t_3 \end{cases} \quad (1)$$

Definition 3: Let the fuzzy numbers be denoted as $A = (t_{11}, t_{12}, t_{13})$ and $B = (t_{21}, t_{22}, t_{23})$. Operational laws on these numbers are denoted in the Equations (2-7) below

$$A(+)B = (t_{11}, t_{12}, t_{13})(+)(t_{21}, t_{22}, t_{23}) = (t_{11} + t_{21}, t_{12} + t_{22}, t_{13} + t_{23}) \quad (2)$$

$$A(-)B = (t_{11}, t_{12}, t_{13})(-)(t_{21}, t_{22}, t_{23}) = (t_{11} - t_{21}, t_{12} - t_{22}, t_{13} - t_{23}) \quad (3)$$

$$A(+)B = (t_{11}, t_{12}, t_{13})(\times)(t_{21}, t_{22}, t_{23}) = (t_{11}t_{21}, t_{12}t_{22}, t_{13}t_{23}) \quad (4)$$

$$A(+)B = (t_{11}, t_{12}, t_{13})(\div)(t_{21}, t_{22}, t_{23}) = (\frac{t_{11}}{t_{23}}, \frac{t_{12}}{t_{22}}, \frac{t_{13}}{t_{21}}) \quad (5)$$

$$kA = (kt_{11}, kt_{12}, kt_{13}) \quad (6)$$

$$A^{-1} = \left(\frac{1}{t_{23}}, \frac{1}{t_{22}}, \frac{1}{t_{21}}\right) \quad (7)$$

Definition 4: *Linguistic variables:* Linguistic variables are variables which use linguistic expressions like words and sentences of a language to express their values. These can be transformed to triangular fuzzy numbers utilizing conversion scales. Table 3 tabulates the linguistic variables and fuzzy ratings for the alternatives and criteria, respectively.

Table 3 Linguistic Variables and Corresponding Fuzzy Ratings used for Criteria

Linguistic variables	Triangular fuzzy numbers
VH	(0.8,0.9,1)
H	(0.7,0.8,0.9)
MH	(0.6,0.7,0.8)
M	(0.35,0.5,0.65)
ML	(0.2,0.35,0.5)
L	(0.05,0.2,0.35)
VL	(0,0.1,0.2)

This segment shares a concise explanation of MCDM processes exercised in this paper for the supplier selection.

3.3 Fuzzy VIKOR

Fuzzy VIKOR is a MCDM technique that has gained popularity in the recent years due to its features and capabilities. The VIKOR method was developed by Opricovic, (1998). This method has various advantages over some other MCDM techniques. It considers individual regret minimization and group utility maximization as compared to TOPSIS. It also entirely reflects the subjective preferences of decision makers (Wan et al., 2013, Opricovic and Tzeng, 2004). Another benefit of VIKOR method is that ideal solution is introduced to multi-criteria based on the specific degree of "closeness" (Opricovic and Tzeng, 2004). Some of the recent areas of application of this method are mentioned in Table 4.

Table 4 Previous Studies on Fuzzy VIKOR for Solving MCDM Problem

S.No.	Authors	Application Area	Industry, Country
1	Soner et al. (2017)	Selection of hatch cover design of the ship	Maritime transportation industry, Turkey
2	Chang (2014)	Evaluation of hospital service	Health industry, China
3	Gupta et al. (2016)	Selection of plant location	Manufacturing industry, India
4	Li and Zhao (2016)	Functioning assessment of eco-industrial thermal power plant	Thermal power industry, China
5	Jati (2012)	Comparison of University Webometrics Ranking	Education industry
6	Mandal et al. (2015)	Identification of human error and ordering of risk in overhead crane processes	Construction industry, India
7	Liu et al. (2016)	Assessment of health-care waste disposal methods	Health industry, China
8	Wu et al. (2016)	Supplier selection for a nuclear power plant	Nuclear industry, China
9	Tiwari et al. (2016)	Evaluation of product design	Manufacturing industry, India
10	Yücenur et al. (2012)	Selection of insurance company for investing in by foreign investors	Insurance industry, Turkey

Fuzzy VIKOR method steps has been presented below

- Step 1: Identification of scope and objective of the problem.
- Step 2: Specifying and illustrating the collection of important attributes of the problem.
- Step 3: Obtain the weights using linguistic variables.
  The linguistic variables were translated in terms of triangular fuzzy numbers as listed in Table 3 respectively for further calculations.
- Step 4: Creating a decision matrix.

The decision matrices were developed based on the inputs obtained from each decision maker (DM_1 to DM_6). Here s_{op} is the ratings of alternatives ($A_1,A_2,\ldots A_o$) vis-à-vis criteria ($C_1,C_2,\ldots C_p$) given by decision makers DM_l. Firstly, s_{op} is written in the terms of linguistic variables and next it is converted into triangular fuzzy numbers (Refer Table 3.).

$$DM_l = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_o \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_p \end{array} \\ \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1p} \\ s_{21} & s_{22} & \cdots & s_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ s_{o1} & s_{o2} & \cdots & s_{op} \end{bmatrix} \end{array}$$

- Step 5: Aggregation of the preferences of decision makers.
  - In this step, the preferences of criteria and alternatives as decided by decision makers are aggregated based on;

- ***Aggregation of criteria weights***

  Let the weight provided by the decision maker DM_l to criteria C_f be characterized by $h_{fu} = (a_{fu},b_{fu},c_{fu})$, f=1,2,…p, u= 1,2,…l.

  The aggregated fuzzy weight of criteria C_f is calculated by using Equation 9

  $$H_f = (a_f, b_f, c_f) \quad (9)$$

  Where $a_f = \min\{a_f\}_u$, $b_f = \frac{1}{u}\sum_{u=1}^{L}\{b_f\}_u$, $c_f = \max\{c_f\}_u$

- ***Aggregation of alternative ratings***

  Let the rating provided by decision maker DM_l to alternative A_i be characterized by $d_{ifu} = (j_{ifu},k_{ifu},m_{ifu})$, i=1,2,…o, f=1,2,…p, u= 1,2,…l. .

  The aggregated fuzzy rating of alternative A_i with respect to criteria C_f is calculated by using Equation 10

  $$D_{if} = (j_{if}, k_{if}, m_{if}) \quad (10)$$

  Where $j_{if} = \min\{j_{if}\}_u$, $k_{if} = \frac{1}{u}\sum_{u=1}^{L}\{k_f\}_u$, $m_{if} = \max\{m_{if}\}_u$

  Thus the aggregated fuzzy rating of alternatives is constructed.

- Step 6: Defuzzification of fuzzy weight of criteria and developing the fuzzy decision matrix.

  The process of defuzzification is done for locating the Best Nonfuzzy Performance value (BNP). Various methods such as α-cut, center of area (COA) and mean of maxima (MOM) can be used to calculate the BNP value. (Hsieh et al., 2004; Zhao and Govind, 1991; Opricovic and Tseng, 2003). Here COA method is used as it is simple, practical and doesn't require preferences of evaluators. (Wu et al., 2009). The value of BNP is calculated by Equation 11

  $$X_{if} = j_{if} + \frac{(m_{if}-j_{if})+(k_{if}-j_{if})}{3}, \forall f \quad (11)$$

- Step 7: Determination of the NIS and PIS values of each criterion rating. f = 1,2,…,p.
  $A_p^- = min\, A_{if}$ (12)
  $A_p^* = max\, A_{if}$ (13)
  Here, negative ideal solution (NIS) for pth criterion is denoted by A_p^- and positive ideal solution (PIS) by A_p^*.
- Step 8: Calculation of S_i and R_i values.
  The values of S_i and R_i are computed using Equations 14 and 15 respectively
  $S_i = \sum_{f=1}^{p} H_f \left[\frac{A_f^* - A_{if}}{A_f^* - A_f^-}\right]$ (14)
  $R_i = max_f \left[H_f \left(\frac{A_f^* - A_{if}}{A_f^* - A_f^-}\right)\right]$ (15)
  Here, S_i represents distance rate of ith alternative to PIS and similarly R_i to NIS.
- Step 9: Calculate the gaps of ranking.
  The values of gaps of ranking Q_i are calculated using Equation 16
  $Q_i = v\left(\frac{S^i - S^*}{S^- - S^*}\right) + (1 - v)\left(\frac{R^i - R^*}{R^- - R^*}\right), i = 1,2,\ldots,o$ (16)
  Here, $S^- = max(S_i)$, $S^* = min(S_i)$, $R^- = max(R_i)$, $R^* = min(R_i)$, and v denotes the weight of strategy of the majority of criteria.
- Step 10: Ranking of alternatives.
  The alternatives are ranked in descending order of S_i, R_i and Q_i values. Thus three ranking lists are formed where the best alternative has the lowest values.
- Step 11: Proposal of a compromise solution. The best alternative is selected on the basis of lowest values of Q_i iff the following 2 conditions are satisfied.
  The best alternative ranked by Q value $Q(A^{(1)})$ has an allowable advantage over the second best alternative $Q(A^{(2)})$
  $Q\left(A^{(2)}\right) - Q\left(A^{(1)}\right) = \frac{1}{o-1}$ (17)
- Stability in decision making. S and R rankings should also indicate A (1) to be the best alternative.
- Step 12: Selection of the best compromise solution.

3.4 Solution Framework

Figure 2 gives the solution framework for the problem. From the Figure 2 the we can infer that this problem focuses largely between manufacturer and supplier. The primary objective of the paper is to choose the most optimal green supplier. To achieve this a set of GSCM criteria are selected and questionnaires are established respectively. Responses for the questionnaire are given by six Decision-Maker's (DM's) and they are formulated as a table with weights for each criteria. Since DM's play a crucial role in the whole process, experienced DM's are chosen for the process. Using MCDM techniques the rankings of the suppliers is established.

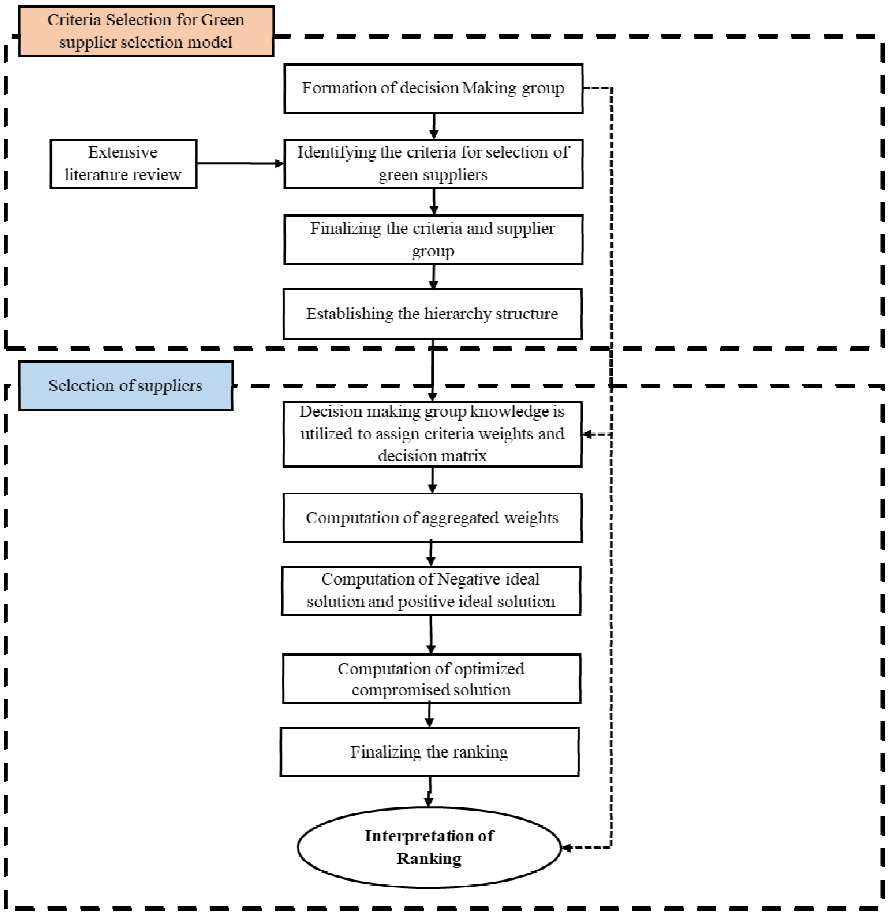

Figure 2 Solution Framework

4. Application of Solution Methodology

4.1 Data Collection

The objective of this study is to choose the most optimal green supplier considering the GSCM criteria. In this case, 6 decision makers, 7 criteria, 26 sub-criteria and 10 alternative suppliers have been considered (Refer Table 1). The decision makers weighed their preferences based on the significance of the criteria and rated the alternatives based on the criteria which are tabulated in Table 5. These linguistic variables were translated in terms of triangular fuzzy numbers as listed in Table 3 respectively for further calculations. The best compromise solution is selected according to the rankings obtained.

4.2 Calculation's and Results

The weights for the criteria obtained from the decision makers is shown in Table 5. Using Equation 9, the weights provided by the decision makers are normalized. The normalized weights are defuzzified using Equation 11 which is shown in last column of Table 5. In order to understand the performance of alternate suppliers with respect to criteria, the pairwise comparison scores are obtained. The scores provided by decision makers 1 is presented in

Table 6. The scores obtained from the 7 Decision makers are normalized using Equation 10 which is shown in Table 7. The equations 12 and 13 are used to compute the negative and positive ideal solution. After computing the NIS and PIS, the S_j and R_j scores for all the alternatives are computed. Finally, Q_j score is computed as shown in Table 8. Using the S_j, R_j, and Q_j the suppliers are ranked as shownin Table 8. The scupplier A1 is chosen as the best supplier based on S_j, R_j, and Q_j, scores.

Table 5 Triangular Fuzzy Values of Criteria and Sub Criteria as Weighed by the Decision Makers

Criteria	Decision Makers												Normalized Weights
	DM_1		DM_2		DM_3		DM_4		DM_5		DM_6		
C1	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	0.164
C2	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	0.159
C3	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	MP	(0.2,0.35,0.5)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	0.108
C4	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	0.136
C5	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	0.122
C6	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	0.154
C7	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	0.127
SC11	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	0.043
SC12	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	0.04
SC13	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	0.042
SC14	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	MH	(0.6,0.7,0.8)	0.039
SC21	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	0.042
SC22	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	0.037
SC23	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	MH	(0.6,0.7,0.8)	VH	(0.8,0.9,1)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	0.04
SC24	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	0.039
SC31	M	(0.35,0.5,0.65)	MP	(0.2,0.35,0.5)	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	0.026

SC 32	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	0.043
SC 33	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	0.04
SC 41	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	0.042
SC 42	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	0.037
SC 43	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	0.032
SC 44	M	(0.35,0.5,0.65)	MP	(0.2,0.35,0.5)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	0.025
SC 45	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	0.03
SC 51	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	0.043
SC 52	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	0.042
SC 53	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	0.037
SC 61	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	0.043
SC 62	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	MH	(0.6,0.7,0.8)	0.04
SC 63	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	0.043
SC 64	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	0.029
SC 71	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	0.043
SC 72	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	0.042
SC 73	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)	0.042

Table 6 Pairwise Comparion Score for Alternatives Provided by Decision Maker 1

	Alternatives													
	A_1		**A_2**		**A_3**		**A_4**		**A_5**		**A_6**		**A_7**	
C1	VH	(0.8,0.9,1)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	VH	(0.8,0.9,1)	L	(0.05,0.2,0.35)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)
C2	H	(0.7,0.8,0.9)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	MH	(0.6,0.7,0.8)	VL	(0,0.1,0.2)	L	(0.05,0.2,0.35)	MH	(0.6,0.7,0.8)
C3	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	VL	(0,0.1,0.2)	ML	(0.2,0.35,0.5)	MH	(0.6,0.7,0.8)
C4	VL	(0,0.1,0.2)	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	ML	(0.2,0.35,0.5)	H	(0.7,0.8,0.9)	ML	(0.2,0.35,0.5)

C5	L	(0.05,0.2,0.35)	L	(0.05,0.2,0.35)	L	(0.05,0.2,0.35)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)
C6	L	(0.05,0.2,0.35)	VL	(0,0.1,0.2)	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	MH	(0.6,0.7,0.8)	VH	(0.8,0.9,1)	ML	(0.2,0.35,0.5)
C7	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	M	(0.35,0.5,0.65)	H	(0.7,0.8,0.9)	VL	(0,0.1,0.2)	M	(0.35,0.5,0.65)	H	(0.7,0.8,0.9)
SC11	H	(0.7,0.8,0.9)	ML	(0.2,0.35,0.5)	M	(0.35,0.5,0.65)	VH	(0.8,0.9,1)	VL	(0,0.1,0.2)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)
SC12	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	ML	(0.2,0.35,0.5)	H	(0.7,0.8,0.9)	L	(0.05,0.2,0.35)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)
SC13	VH	(0.8,0.9,1)	L	(0.05,0.2,0.35)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	L	(0.05,0.2,0.35)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)
SC14	H	(0.7,0.8,0.9)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	VH	(0.8,0.9,1)	ML	(0.2,0.35,0.5)	VH	(0.8,0.9,1)	H	(0.7,0.8,0.9)
SC21	MH	(0.6,0.7,0.8)	L	(0.05,0.2,0.35)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	VL	(0,0.1,0.2)	L	(0.05,0.2,0.35)	MH	(0.6,0.7,0.8)
SC22	H	(0.7,0.8,0.9)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	MH	(0.6,0.7,0.8)	VL	(0,0.1,0.2)	L	(0.05,0.2,0.35)	MH	(0.6,0.7,0.8)
SC23	H	(0.7,0.8,0.9)	VL	(0,0.1,0.2)	ML	(0.2,0.35,0.5)	M	(0.35,0.5,0.65)	VL	(0,0.1,0.2)	ML	(0.2,0.35,0.5)	H	(0.7,0.8,0.9)
SC24	VH	(0.8,0.9,1)	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	H	(0.7,0.8,0.9)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	H	(0.7,0.8,0.9)
SC31	H	(0.7,0.8,0.9)	M	(0.35,0.5,0.65)	H	(0.7,0.8,0.9)	VH	(0.8,0.9,1)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	H	(0.7,0.8,0.9)
SC32	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	L	(0.05,0.2,0.35)	L	(0.05,0.2,0.35)	H	(0.7,0.8,0.9)
SC33	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	VL	(0,0.1,0.2)	ML	(0.2,0.35,0.5)	M	(0.35,0.5,0.65)
SC41	VL	(0,0.1,0.2)	M	(0.35,0.5,0.65)	ML	(0.2,0.35,0.5)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	VH	(0.8,0.9,1)	M	(0.35,0.5,0.65)
SC42	L	(0.05,0.2,0.35)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	ML	(0.2,0.35,0.5)
SC43	VL	(0,0.1,0.2)	MH	(0.6,0.7,0.8)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	ML	(0.2,0.35,0.5)	H	(0.7,0.8,0.9)	L	(0.05,0.2,0.35)
SC44	L	(0.05,0.2,0.35)	L	(0.05,0.2,0.35)	L	(0.05,0.2,0.35)	L	(0.05,0.2,0.35)	MH	(0.6,0.7,0.8)	VH	(0.8,0.9,1)	M	(0.35,0.5,0.65)
SC45	ML	(0.2,0.35,0.5)	ML	(0.2,0.35,0.5)	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	ML	(0.2,0.35,0.5)
SC51	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	H	(0.7,0.8,0.9)	M	(0.35,0.5,0.65)
SC52	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	VL	(0,0.1,0.2)	ML	(0.2,0.35,0.5)	ML	(0.2,0.35,0.5)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)
SC53	L	(0.05,0.2,0.35)	L	(0.05,0.2,0.35)	L	(0.05,0.2,0.35)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)
SC61	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	M	(0.35,0.5,0.65)	H	(0.7,0.8,0.9)	L	(0.05,0.2,0.35)
SC62	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	ML	(0.2,0.35,0.5)	H	(0.7,0.8,0.9)	M	(0.35,0.5,0.65)	M	(0.35,0.5,0.65)

SC63	ML	(0.2,0.35,0.5)	VL	(0,0.1,0.2)	L	(0.05,0.2,0.35)	VL	(0,0.1,0.2)	MH	(0.6,0.7,0.8)	H	(0.7,0.8,0.9)	ML	(0.2,0.35,0.5)
SC64	L	(0.05,0.2,0.35)	VL	(0,0.1,0.2)	ML	(0.2,0.35,0.5)	L	(0.05,0.2,0.35)	MH	(0.6,0.7,0.8)	VH	(0.8,0.9,1)	ML	(0.2,0.35,0.5)
SC71	VH	(0.8,0.9,1)	VH	(0.8,0.9,1)	M	(0.35,0.5,0.65)	H	(0.7,0.8,0.9)	VL	(0,0.1,0.2)	M	(0.35,0.5,0.65)	H	(0.7,0.8,0.9)
SC72	VH	(0.8,0.9,1)	MH	(0.6,0.7,0.8)	M	(0.35,0.5,0.65)	VH	(0.8,0.9,1)	L	(0.05,0.2,0.35)	MH	(0.6,0.7,0.8)	VH	(0.8,0.9,1)
SC73	H	(0.7,0.8,0.9)	H	(0.7,0.8,0.9)	MH	(0.6,0.7,0.8)	MH	(0.6,0.7,0.8)	VL	(0,0.1,0.2)	ML	(0.2,0.35,0.5)	H	(0.7,0.8,0.9)

Table 7 Dufuzzified Values of the Ratings

Criteria	Weights	Alternatives						
		A_1	A_2	A_3	A_4	A_5	A_6	A_7
C1	0.164	0.85	0.494	0.436	0.85	0.225	0.514	0.656
C2	0.159	0.75	0.231	0.389	0.65	0.239	0.244	0.65
C3	0.108	0.75	0.65	0.656	0.8	0.231	0.283	0.65
C4	0.136	0.225	0.411	0.275	0.35	0.506	0.8	0.358
C5	0.122	0.275	0.244	0.253	0.514	0.494	0.639	0.514
C6	0.154	0.267	0.219	0.275	0.236	0.65	0.717	0.358
C7	0.127	0.856	0.794	0.525	0.806	0.167	0.494	0.844
SC11	0.043	0.806	0.358	0.503	0.85	0.236	0.694	0.806
SC12	0.04	0.817	0.358	0.494	0.839	0.386	0.7	0.817
SC13	0.042	0.85	0.333	0.583	0.85	0.231	0.794	0.85
SC14	0.039	0.844	0.367	0.561	0.85	0.244	0.8	0.85
SC21	0.042	0.794	0.283	0.375	0.75	0.172	0.267	0.756
SC22	0.037	0.789	0.244	0.367	0.65	0.161	0.267	0.75
SC23	0.04	0.817	0.261	0.358	0.65	0.172	0.292	0.761
SC24	0.039	0.789	0.292	0.367	0.661	0.178	0.275	0.761
SC31	0.026	0.75	0.656	0.756	0.794	0.167	0.292	0.628
SC32	0.043	0.75	0.639	0.756	0.8	0.178	0.283	0.65
SC33	0.04	0.744	0.656	0.661	0.806	0.236	0.292	0.628
SC41	0.042	0.167	0.411	0.283	0.375	0.503	0.806	0.367
SC42	0.037	0.231	0.403	0.275	0.342	0.525	0.806	0.367
SC43	0.032	0.167	0.431	0.275	0.358	0.494	0.806	0.35
SC44	0.025	0.231	0.442	0.244	0.342	0.517	0.8	0.358
SC45	0.03	0.225	0.45	0.233	0.261	0.497	0.8	0.35
SC51	0.043	0.283	0.267	0.253	0.514	0.425	0.744	0.583
SC52	0.042	0.283	0.236	0.247	0.506	0.486	0.656	0.525
SC53	0.037	0.267	0.172	0.253	0.514	0.514	0.639	0.494

SC61	0.043	0.283	0.225	0.267	0.231	0.639	0.706	0.342
SC62	0.04	0.258	0.239	0.283	0.244	0.65	0.694	0.358
SC63	0.043	0.275	0.161	0.275	0.156	0.7	0.839	0.35
SC64	0.029	0.258	0.239	0.275	0.231	0.65	0.711	0.35
SC71	0.043	0.856	0.8	0.514	0.794	0.161	0.494	0.844
SC72	0.042	0.861	0.789	0.506	0.806	0.172	0.494	0.85
SC73	0.042	0.861	0.8	0.583	0.806	0.167	0.506	0.844

Table 8 Ranking of Alternatives

Alternatives	S_j	Ranks	R_j	Ranks	Q_j	Ranks
A_1	0.046	**1**	0.008	**1**	0	**1**
A_2	0.376	5	0.04	5	0.665	5
A_3	0.315	4	0.029	4	0.467	4
A_4	0.156	2	0.027	2	0.349	2
A_5	0.839	7	0.043	7	1	7
A_6	0.762	6	0.043	6	0.948	6
A_7	0.214	3	0.029	3	0.412	3

5. Findings and Discussions

On comparison of weights, the significant criteria which highly influences the results are Environmental Management systems (C1), Eco-Design (C2) and Current Environmental Impact (C6) with weights 0.164, 0.159, 0.154 and sub-criteria especially related to computer accessories like ISO-14001 (SC11) and Product Design for ecofriendly disposal (SC23) with weights 0.043 and 0.04 respectively since these criteria are related to environment on first-hand basis and chosen specifically to computer accessories. Li et al., (2015) described that eco design could enhance the environment to new stage in efficient production, fewer emission and sustainable development using an article regarding consumer electronics. Donnelly et al., (2006) discussed how Lucent's wireless business unit, Mobility Solutions employment of Eco-design and Environmental Management systems in their products befitted them. The sub criteria, selling excess inventory/ materials (SC31), is weakly associated with green practices with weight 0.026 since it belongs to the least weighted group, investment recovery criteria (C3), which is 0.108 which Zhu and sarkis (2004) discussed that even though investment recovery is a traditional business practice and considered a green practice since it can reduce waste that may have otherwise been disposed, investment recovery may not be the most sustainable practice. From the Table 8 it can be observed that A1 seems to be the best alternative. Form Table 8, it can be observed that A1 has high weights in Environmental Management system (C1) along with its sub-criteria ISO-14001 and Collaboration with suppliers and customers for cleaner, greener production (C7) followed by Eco-Design (C2) along with its sub-criteria Product Design for ecofriendly disposal (SC23) and Investment Recovery (C3). From the above observations it can be inferred that A1's high ranking is

because of its increased focus on the highly weighted criteria like C1 and C2 as they are more intimately related to environment. Preferences regarding the significance of the criteria and rating of alternatives vis-à-vis criteria are provided by the expert decision makers. The rating of alternatives with respect to criteria and sub criteria given by decision makers is made available as Appendix 1. It is obtained as one which indicates perfect association between the rankings obtained by fuzzy VIKOR method. The rankings indicate that the company could select alternative A_1 as its green supplier to best strengthen the GSCM practices in the supply chain.

6. Implications

The main objective of the study to propose the criteria for selecting green suppliers for computers accessories manufacturing which is the important theoretical contribution of this work. With the proposed set of criteria, the managers of computer accessories and part manufactuers can rank the suppliers for implementing green supply chain management. The proposed solution framework can be used to effectively prioritize the weights of the criteria and ranking of the supliers. The major practical implication of this study is the demonstration of a case study using which the practitioners can under and excute the process of suppliers selection.

7. Conclusion

Indian companies are still new to the concept of GSCM, but they are beginning to understand the significance of GSCM in order to enhance their green image and comply with the environmental rules. Thus various companies are beginning to show commitment towards implementation of GSCM. This research aims to present a case study of an Indian computer accessories company which needs to select green suppliers as a part of implementing GSCM practices. This case study presents a real world MCDM problem in a linguistic environment for selection of green supplier. Here, the extensions of VIKOR method under a fuzzy environment has been proposed. Thereafter, with a perfect association between the results obtained indicating their reliability. Thus the best green supplier can be selected by the company to strengthen their GSCM practices.

In this work, the suggested framework demonstrated can be easily adopted by managers of any company for choosing the best green suppliers out of various potential suppliers for that company. The hierarchal model as demonstrated in Figure 1 can benefit the firm by functioning as a roadmap to understand the evaluation and selection of best green supplier. Also, as the strengths and weaknesses of supplier in the area of GSCM is discovered, the firm can work with its suppliers to enhance their strengths and actions are taken to reduce their weaknesses. Managers can also operate with selected group of suppliers to develop, enhance and benchmark enhanced green processes and products. This can significantly improve supplier-firm relations and help select the best supplier for future collaboration.

However, a few limitations could exist limitations in the terms of delivery lead time, rating and reliability of suppliers, etc. Future research can be done by using other MCDM techniques such as ELECTRE, COPRAS etc. Integrated MCDM models like DEA-VIKOR, DEA-TOPSIS can also be developed for simultaneous processing of numerical and linguistic input data of the suppliers. The results from this research can be compared to the results obtained from other methods.

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Appendix 1

Table 9a Rating of Alternatives with Respect to Criteria and Sub Criteria as Given by Decision Maker 1

	DM1						
	A1	A2	A3	A4	A5	A6	A7
C1	(0.8,0.9,1)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
C2	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.6,0.7,0.8)
C3	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.6,0.7,0.8)
C4	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
C5	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
C6	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.2,0.35,0.5)
C7	(0.8,0.9,1)	(0.8,0.9,1)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.7,0.8,0.9)
SC11	(0.7,0.8,0.9)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
SC12	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
SC13	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)
SC14	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.8,0.9,1)	(0.7,0.8,0.9)
SC21	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.6,0.7,0.8)
SC22	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.6,0.7,0.8)
SC23	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC24	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC31	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC32	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
SC33	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.35,0.5,0.65)
SC41	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC42	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
SC43	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC44	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC45	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
SC51	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.35,0.5,0.65)
SC52	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
SC53	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
SC61	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC62	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
SC63	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC64	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.2,0.35,0.5)
SC71	(0.8,0.9,1)	(0.8,0.9,1)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.7,0.8,0.9)
SC72	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)

SC73	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.7,0.8,0.9)

Table 9b Rating of Alternatives with Respect to Criteria and Sub Criteria as Given by Decision Maker 2

	DM2						
	A1	A2	A3	A4	A5	A6	A7
C1	(0.7,0.8,0.9)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
C2	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.35,0.5,0.65)
C3	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.6,0.7,0.8)
C4	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.35,0.5,0.65)
C5	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.35,0.5,0.65)
C6	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
C7	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC11	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
SC12	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)
SC13	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.8,0.9,1)	(0.7,0.8,0.9)
SC14	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)
SC21	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.6,0.7,0.8)
SC22	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC23	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC24	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.6,0.7,0.8)
SC31	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
SC32	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.35,0.5,0.65)
SC33	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)
SC41	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC42	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC43	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC44	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
SC45	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC51	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
SC52	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
SC53	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.2,0.35,0.5)
SC61	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC62	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.2,0.35,0.5)
SC63	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC64	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC71	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)
SC72	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.8,0.9,1)
SC73	(0.8,0.9,1)	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.7,0.8,0.9)

Table 9c Rating of Alternatives with Respect to Criteria and Sub Criteria as Given by Decision Maker 3

	DM3						
	A1	A2	A3	A4	A5	A6	A7
C1	(0.7,0.8,0.9)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
C2	(0.6,0.7,0.8)	(0,0.1,0.2)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.6,0.7,0.8)
C3	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)

C4	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
C5	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.2,0.35,0.5)
C6	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
C7	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)
SC11	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)
SC12	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)
SC13	(0.7,0.8,0.9)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
SC14	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)
SC21	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC22	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
SC23	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.6,0.7,0.8)
SC24	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC31	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.35,0.5,0.65)
SC32	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
SC33	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC41	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC42	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC43	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
SC44	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
SC45	(0,0.1,0.2)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC51	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
SC52	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
SC53	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.35,0.5,0.65)
SC61	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
SC62	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC63	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC64	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.2,0.35,0.5)
SC71	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC72	(0.8,0.9,1)	(0.8,0.9,1)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.7,0.8,0.9)
SC73	(0.8,0.9,1)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.8,0.9,1)

Table 9d Rating of Alternatives with Respect to Criteria and Sub Criteria as Given by Decision Maker 4

	DM4						
	A1	A2	A3	A4	A5	A6	A7
C1	(0.8,0.9,1)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.6,0.7,0.8)
C2	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.6,0.7,0.8)
C3	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
C4	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
C5	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
C6	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.2,0.35,0.5)
C7	(0.8,0.9,1)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC11	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.8,0.9,1)	(0.7,0.8,0.9)
SC12	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.8,0.9,1)
SC13	(0.7,0.8,0.9)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
SC14	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.8,0.9,1)	(0.7,0.8,0.9)
SC21	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC22	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.6,0.7,0.8)
SC23	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC24	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
SC31	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)
SC32	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC33	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
SC41	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
SC42	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC43	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC44	(0,0.1,0.2)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC45	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC51	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
SC52	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.2,0.35,0.5)
SC53	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
SC61	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.2,0.35,0.5)
SC62	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC63	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC64	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC71	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.8,0.9,1)
SC72	(0.8,0.9,1)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC73	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)

Table 9e Rating of Alternatives with Respect to Criteria and Sub Criteria as Given by Decision Maker 5

	DM5						
	A1	A2	A3	A4	A5	A6	A7
C1	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
C2	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
C3	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.6,0.7,0.8)
C4	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
C5	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
C6	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
C7	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.7,0.8,0.9)
SC11	(0.7,0.8,0.9)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
SC12	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)
SC13	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)
SC14	(0.7,0.8,0.9)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)
SC21	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
SC22	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC23	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC24	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
SC31	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.6,0.7,0.8)
SC32	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)
SC33	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.6,0.7,0.8)
SC41	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC42	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
SC43	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC44	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC45	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC51	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
SC52	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.35,0.5,0.65)
SC53	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
SC61	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC62	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
SC63	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.2,0.35,0.5)
SC64	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC71	(0.8,0.9,1)	(0.8,0.9,1)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.7,0.8,0.9)
SC72	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC73	(0.8,0.9,1)	(0.8,0.9,1)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.7,0.8,0.9)

Table 9f Rating of Alternatives with Respect to Criteria and Sub Criteria as Given by Decision Maker 6

	DM6						
	A1	A2	A3	A4	A5	A6	A7
C1	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
C2	(0.7,0.8,0.9)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
C3	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.35,0.5,0.65)
C4	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.35,0.5,0.65)
C5	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.6,0.7,0.8)
C6	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.35,0.5,0.65)
C7	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.8,0.9,1)
SC11	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)
SC12	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.8,0.9,1)	(0.7,0.8,0.9)
SC13	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)
SC14	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.8,0.9,1)
SC21	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.7,0.8,0.9)
SC22	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0.6,0.7,0.8)
SC23	(0.8,0.9,1)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC24	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC31	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.35,0.5,0.65)
SC32	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC33	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)
SC41	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.2,0.35,0.5)
SC42	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC43	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC44	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.35,0.5,0.65)
SC45	(0,0.1,0.2)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC51	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.6,0.7,0.8)	(0.35,0.5,0.65)
SC52	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.6,0.7,0.8)
SC53	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0.35,0.5,0.65)	(0.2,0.35,0.5)
SC61	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.7,0.8,0.9)	(0.05,0.2,0.35)
SC62	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.2,0.35,0.5)
SC63	(0.2,0.35,0.5)	(0,0.1,0.2)	(0.05,0.2,0.35)	(0,0.1,0.2)	(0.6,0.7,0.8)	(0.7,0.8,0.9)	(0.2,0.35,0.5)
SC64	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
SC71	(0.7,0.8,0.9)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.6,0.7,0.8)	(0,0.1,0.2)	(0.2,0.35,0.5)	(0.7,0.8,0.9)
SC72	(0.8,0.9,1)	(0.6,0.7,0.8)	(0.2,0.35,0.5)	(0.7,0.8,0.9)	(0.05,0.2,0.35)	(0.35,0.5,0.65)	(0.8,0.9,1)
SC73	(0.8,0.9,1)	(0.7,0.8,0.9)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.05,0.2,0.35)	(0.2,0.35,0.5)	(0.7,0.8,0.9)

Barriers to Adoption of Digitization in Supply Chain Management: Implication on Sustainable Goal

Krishna Kumar Dadsena

Abstract

In success of the modern supply chain the role of advanced technologies plays an important role in not only the improvement of business performance but also enhance the competitive advantages in achieving the sustainable goals. However, based on the trade journal, scientific literature, and discussion with the experts it is observed that, the adoption of the digitization is still encountering the several challenges. Our study identified the barriers in supply chain digitization and its impact on SDGs. The barriers are categories in four main criteria and twelve sub criteria and prioritized using Analytic Hierarchy Process (AHP). The results of the study indicated that administrative barrier is most crucial criteria in adoption of supply chain digitization. This study helps managerial decision making by providing structural thinking regarding interlink among the barriers and their impact on sustainable goals.

Keywords: *Digitization; Sustainable Goals; Barriers in Supply Chain Digitization; Analytic Hierarchy Process.*

1. Introduction

In the fast pace growing business environment the supply chain practitioners motivated towards the adoption of new technologies to match with the global supply chain. As in success of the modern supply chain the role of advanced information technology plays a vital role for improvement of business performance as well as benefits of the organisation (Gupta et al., 2020).These includes the technologies which enables streamline the process, improve the capability of the operations and systems and enhance the analytical practice to transform the supply chain of an organization. The use of advanced technologies also helps in better results and benefits in operations and performance (Wang et al., 2018). Hence, this new world of digitization offers organizations a better solution for their business challenges.

The supply chain digitization helps the business in attaining the high customer service, coordination among the different stages. The digital transformation helps in accelerate the business operations in several ways such as demand and planning management, lead time management, productions, and operations management to meet the vision of organizations. Along with the advantages the recent time organizations also need to attain the goals related sustainable development (Mondejar eta al., 2021). Recent studies pointed out that the supply chain digitization also has an impact on sustainable development goals (SDGs) (Secundo et al., 2022; Nayak et al., 2022). Digitization of supply chain has not only become one of the vital

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processes to compete with global competitors but also helps in attaining some important SDGs.

Despite of several benefits of digitization the organizations are facing several hindrances in integration and implementation. Thus, in order to compete with the global market scenario, the identification of key barriers in supply chain digitization has become the integral part of the business. We identified the barriers in supply chain digitization and its link with SDGs. For example, the high initial investment, lack of skilled human resource, lack of research and development wing and cyber security. These barriers affect the organizations operations and policy under the uncertain, competitive and transforming business environment.

Even though, there are studies resalted to Supply chain digitization, authors indicated the further research is require to explore how the barriers affects the sustainable development goals. As sustainability has become imperative part of any organizations which organizations must responds to remain competitive, and its linkage with supply chain need to be study (Ciampi et al., 2022). The existing studies mainly focuses on barriers however the linkage of those has not been highlighted properly. Hence, our study captures the linkage of barriers with 17 SDGs, and prioritize it. In order to conduct the study, we have considered energy sector. The Analytical Hierarchy Process (AHP) has been used to rank the barriers. The findings of this study reveal that how the barriers are interlinked with the SDGs, which allows the policy makers to take decision based on both dimension critical barriers as well as SDGs. Considering the above discussion, we frame research question

RQ: **What are the important supply chain digitization barriers and their interconnection with sustainable goals?**

The remaining study is organized as follows. Section 2 presents the key literature related to supply chain digitization and sustainable development goals. Methodology has been discussed in section 3. Section 4 highlighted the results and discussion. Conclusion and implications of the study is highlighted in the section 5.

2. Literature Review

Recent years digitization in becoming more popular as it enables the enhance in competitive benefits considering the global competition (Björkdahl, 2020). Modgil et al. (2021); Singh and Bhanot (2020); Yang and Lin (2020). (2020) highlighted the challenges in supply chain digitization, considering the data utilization and its impact on supply chain. Digitization fastens the pace of supply chain operations for many organization (Annosi et al., 2021) as it encompasses with different such set of tools and techniques like Internet of Things (IOT), data mining, data analytics blockchain technology etc. These advanced technologies aims to improve the firms performance and their benefits (Tsou and Chen, 2022).Digitization also helps supply chain many other benefits like improving the availability and accuracy of

information, optimize the logistics process and helps in efficient inventory management through transparency in operations. (Bigliardi et al., 2022). It enables a new ecosystem by connecting different stages of supply chain to attain the higher performance and profit. The digitization in the operations provides also provides the opportunity to address the issues related to society and environment and helps in attaining the SDGs ((Mondejar eta al., 2021). The role of digitization in supply chain helps in improve the SC prefinance by greater accuracy in forecasting, inventory management, and process design.

Despite of the advantages and benefits of digitization of supply chain its implementation still faces challenges by the organizations. Dawson, (2002) highlighted that management perception on urgency of adoption and investment on technologies as important challenges. According to Agrawal et al., (2019) the lack of clarity on cost and price pressure force managers to rethink about the digitizing their supply chain, as it involves very high investment. Similarly, the budget related issues is also an vital challenges digitization (Falagara Sigala et al., 2020).

In view of administration, implementation of new technology considering the political and policy issues of organizations has been observed as important barrier in digitization. Francesca et. al., (2021) highlighted that coordination among the partners is one of the important barriers in supply chain digitization. In adoption of digitization in supply chain the lack of skilled workers (Ciampi et al., 2022) and poor infrastructure plays an important role, which needs to be managed properly by organization.

The inter organizational and intra organizational policies such as no standard process across the globe, lack of Research facility, and absence of assurance also impedes the SC digitization and which need to be considered for betterment of organizations. As the digital technology adoption also plays an important and trending role in sustainable development of the organization to implement the business strategies in (Borovkov et al., 2021). Authors highlighted the issues related to technology such as competencies about the analytics capabilities, cyber safety and complexity of integrating digital technology are some of the important trends which helps in achieving the sustainable business operations (Borovkov et al., 2021).

Although the gaining importance of digitization of operations and processes in developed countries there is still need to interrelate the sustainable development with digitization, for example,SDG8 (Decent work and economic growth); SDG9(industry innovation and infrastructure); SDG 12 (responsible consumption and productions); SDG17 (Partnership for goals)etc. for global sustainable development (Mondejar et al., 2022; Moomen et al.,2019).Table 1, highlighted the summary of the barriers with the sources.

Table 1 The Barriers in Digitization of Supply Chain

Main Criteria	Sub-Criteria	Source	Link with SDGs by this author
Economic Barriers (EB)	High investment (HI)	Dawson, (2002)	SDG8
	Cost pressure	Experts	
	Budget Availability (BA)	Falagara Sigala et al., (2020)	
Organizational Barriers (AB)	Lack of Coordination (LC)	Francesca Checchinato et. al., (2021)	SDG12
	Lack of Skilled Human Labour (LSHL)	Bhuiyan et al., (2020)	
	Poor Infrastructure (PI)	del Carpio et al., (2022)	
Technical Barriers (TB)	Technical Competencies (TC)	Francesca Checchinato et. al., (2021)	SDG9
	Cyber Safety (CS)	Vafadarnikjoo et al., (2021)	
	Issues in Integration of Technologies (IIT)	Ageron et al., (2020)	

Based on the above arguments, our study targets to identify the barriers in supply chain digitization and how that affects achievements of the SDGs. The barriers are considered as criteria and sub criteria to model and solve using AHP for the energy sector.

3. Methodology and Data

The Analytical Hierarchy Process (AHP) method has been adopted to prioritize the criteria (Main and sub criteria). AHP mainly consists four steps namely as; organizing the problem, data collection, normalization of weights and ranking (Tam and Tummala, 2001). In this methodology the problem considered as hierarchical structure of criteria's, in such case AHP has been considered as one of the user-friendly method (Irfan et al., 2022; Harputlugil et al., 2011). The pairwise comparison has been developed using scale as shown in table 2.

Table 2 Pairwise Comparison Scale

Scale	Meaning (A Factor Compared to B)
1	Very less importance
3	Less important
5	Moderate importance
7	Strong important
9	Highly important
2, 4, 6, 8	Intermediate values
Reciprocals	For inverse comparison

The collection of data from the Supply chain Managers to conduct the research, initial after identifying the main criteria and sub criteria are discussed with two professional and two academicians (researcher) for further inputs. After the inputs from the experts some minor changes have been performed. Then after ten supply chain mangers were targeted for the opinion, however five agreed to provide their response within two weeks of time. Thus, this study adopted the AHP approach to evaluate barriers in supply chain digitization for the energy sector.Figure 1 presented the framework of the proposed study. The steps of the methodology are as below:

Step 1: Framework of Our Study

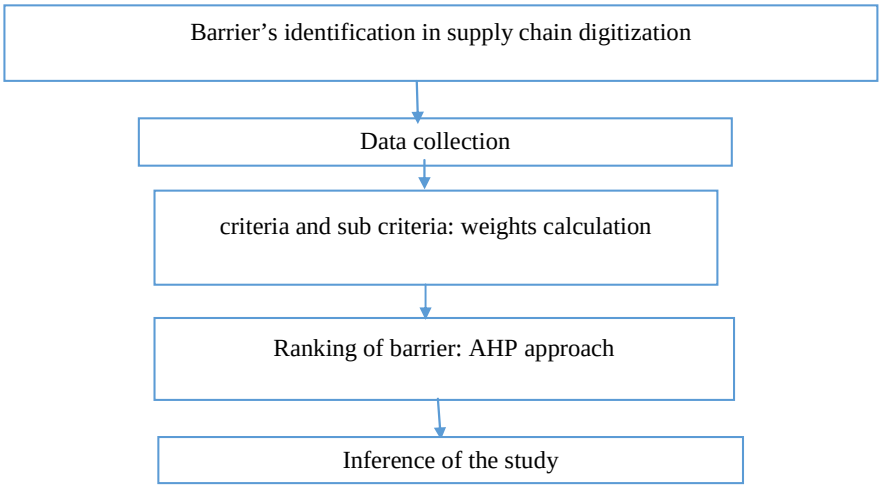

Figure 1 Proposed Research Framework

Step 2: Develop the Pairwise Comparison Matrix

This steps to develop the comparisons matrix experts were asked to perform a series of pairwise comparisons where two elements ((sub) criteria) at a time are compared in terms of importance with respect to a common aspect or property. Previous studies and discussions concerning regarding the elicitation of expert's opinion is more convenient when values express in fuzzy numbers, judgments scale than fixed value scale. Using the scale mentioned in table 2, the expert's opinion has been collected and the pairwise matrix has been constructed. Table 3 shows the pairwise comparison matrix for the main criteria. Similarly, Table 4 (a)-Table (d) presents the pairwise comparison matrix for the sub criteria.

Table: 3 Pairwise Comparison Matrix for the Main Criteria

	EB	OB	TB
EB	(1,1,1)	(1/5,1/6, 1/7)	(1/3, 1/4, 1/5)
OB	(5,6,7)	(1,1,1)	(3, 4, 5)
TB	(3,4,5)	(1/3, 1/4, 1/5)	(1,1,1)
	12	1.783	9.333

Table: 4 (a) Pairwise Comparison Matrix for the Sub Criteria

Economic Barrier (EB)	HI	CP	BA
HI	(1,1,1)	(1/5,1/6, 1/7)	(1/5,1/6, 1/7)
CP	(5,6,7)	(1,1,1)	(3, 4, 5)
BA	(5, 6,7)	(1/3, 1/4, 1/5)	(1,1,1)

Table 4 (b) Pairwise Comparison Matrix for the Sub Criteria

Administrative Barriers (AB)	TLC	LSHL	PI
TLC	(1,1,1)	(3 4, 5)	(4, 5, 6)
LSHL	(1/3, 1/4, 1/5)	(1,1,1)	(1/3, 1/4, 1/5)
PI	(1/4, 1/5, 1/6)	(3, 4, 5)	(1,1,1)

Table 4 (c) Pairwise Comparison Matrix for the Sub Criteria

Technical Barriers (TB)	TC	CS	IIT
TC	(1,1,1)	(1/3, 1/4, 1/5)	(1/3, 1/4, 1/5)
CS	(3, 4, 5)	(1,1,1)	(2, 3, 4)
IIT	(3, 4, 5)	(1/2, 1/3, 1/4)	(1,1,1)

Step 3: Weights calculation: The weights for criteria's (***main and sub criteria)*** has been calculated. Further their local and global weights is calculated and presented in table 5.

Table 5 Weights of the Main and Sub Criteria

	Main criteria Weight	Sub-Criteria	Sub-Criteria Weight	Global Weight
Economic Barriers (EB)	0.125	HI	0.071	0.009
		CP	0.662	0.083
		BA	0.267	0.034
Administrative Barriers (AB)	0.601	TLC	0.667	0.401
		LSHL	0.102	0.061
		PI	0.230	0.138
Technical Barriers (TB)	0.274	TC	0.109	0.030
		CS	0.596	0.163
		IIT	0.295	0.081

4. Results and Discussion

Results of the study reveals that lack of coordination (TLC) raked as top most noteworthy barrier with an average weight of 0.401. Based on the results for main criteria the administrative barriers ranked most important barriers with the weight of 0.601followed by technical barrier and economic barrier at second, third and fourth rank respectively. The role of administration plays an important role in achieving the SDGs, as it helps in innovation in

business operations (SDG9) for mutual benefits with partners. In addition to this the administrative role helps in responsible consumption and productions by using the renewable resources.

Similarly, the pairwise comparisons has been performed for sub criteria and weights has been calculated. Based on the results the TLC ranked first with a weight age of 0.667 and CP for organizing and deploying resources and CS ranked second and third respectively. Similarly absence of CP across the globe is most important issue with an average of 0.662in economic0.662 perspective. And in technological barrier category issue related to cyber safety has been ranked first with an average weight of 0.596.

5. Managerial Implications and Future Scope

Although the supply chain digitization is very growing area of study now a days, but due to the gaining importance of sustainability the SC practitioners should also check how these barriers are interrelated with the SDGs. Results of the study shows that how the different barriers can be handled considering their link with the SDGs. Based on the outcome of the study managers may take ethe decision considering the priority as well as their sustainable goals. This study supports supply chain managers to prepare well to attain the sustainable goals. In future, the study can be validated using other qualitative method such as ISM, Fuzzy *DEMATLE*. Also, it would be interesting to suggest the policy/strategy under the constraint budget.

6. Conclusion

This study helps in understanding the role of digitization in supply chain considering the sustainable development. The present research not only assist in technology advancement challenges but also motivate experts towards the sustainable business practice. The results of our study aids a strategic roadmap in adoption of digital technologies in operations of their business process.

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Influence of Reform of Exchange Rate on Trade Balance: Case of China RMB

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Xiao Wen Lu

Abstract

The exchange rate formation mechanism is an important factor that influences country's currency exchange rate and its trade balance. This paper, based on the data from China and 22 trading countries, using the dynamic panel model and synthetic control method, empirically studies the impact of the reform of RMB exchange rate formation mechanism on China's trade balance. The results show that the appreciation of the RMB will restrain China's trade surplus, and the "8.11 exchange rate reform" in 2015 has caused a negative impact on China's export trade to a certain extent, resulting in an average decline of 1.33% in China's foreign export trade volume from 2015 to 2019.

Keywords: *RMB Exchange Rate Formation Mechanism, China's Trade Balance, Dynamic Panel Model, Synthetic Control Method.*

1. Introduction

On August 11, 2015, the Bank of China announced a significant improvement in the formation of the central parity rate of the RMB against the dollar, in order to make this rate more consistent with the needs of market development. This decision was a continuation of previous rounds of similar reforms and represented an implementation of the Chinese central government's commitment to advancing the reform of market-based exchange rate formation and accelerating the convertibility of the RMB to capital account. Four years later, the RMB exchange rate could rise and fall in both directions, while the normal central bank intervention withdrew from the foreign exchange market. China's progress has been recognized by the International Monetary Fund (IMF), which concluded in its latest report that China's exchange rate was broadly in line with fundamentals. As an economic transition country, China is still in the stage of transition to a free-floating exchange rate system. Since 2005, the RMB exchange rate formation mechanism has undergone two major reforms, especially the "8.11 exchange rate reform" in 2015, which is the closest to the free floating exchange rate system. Considering that the reform of RMB exchange rate formation mechanism has not been finally completed, how to realize the smooth transition in the coming period of time is still a major challenge for China's monetary authorities. Its possible impact on China's trade balance should also attract great attention from the government and academia.

This paper tries to study on the Influence of the Reform of RMB Exchange Rate Formation Mechanism on China's Trade Balance. The paper comprises five sections. First, we analyze the literature reform of exchange rate. In the section three we stud the influence of the reform on China's trade balance. In section four we design an empirical study and the last section conclude and suggest future directions.

2. Literature Review

Chinese scholars hold different views on the impact of the reform of RMB exchange rate formation mechanism on China's trade balance. Some researcher believes that the reform of RMB exchange rate formation mechanism will have an impact on China's trade balance. (Lee et al., 2022; Taghipour and Frayet, 2012; Zoghlami et al., 2016) have shown that exchange rate changes have a significant impact on China's trade balance. The appreciation of the exchange rate will cause China's trade deficit. (Wang and Lee, 2022; Taghipour et al. 2020; Taghipour and Frayret 2010) use the event research method, the paper shows that the appreciation of RMB after the exchange rate reform has restrained the growth of China's export trade. (Ren et al., 2016; Ferjani 2022studied the time-varying impact of RMB exchange rate on China's import and export trade, and found that after the reform of RMB exchange rate formation mechanism in 2005, the impact is mainly reflected in the weakening of export intensity. Wu (2015) found that China's economic environment has become more open after the reform of the RMB exchange rate formation mechanism, and relaxing the floating band of RMB will help to promote economic development (Taghipour, 2009 & 2014; Lebosse et al., 2017).

Other researchers believe that the reform has no impact or little impact on China's trade balance. Lu et al. (2022) found that although the RMB continued to appreciate after the reform of the RMB exchange rate formation mechanism in 2005, it did not have a substantial impact on China's trade balance (Loivet et al. 2020). Das (2019) used the VAR model and found that the impact of exchange rate on the trade balance is not strong. Abbas Ali et al. (2014) studied the impact of exchange rate changes on trade balance. They found that the effect of RMB real exchange rate changes on the improvement of the trade balance between China and South Korea is actually limited (Taghipour et al., 2015; Cauchois et al., 2017).

On the basis of summarizing the existing research, this paper uses the dynamic panel model to empirically test the impact of RMB exchange rate on China's trade balance. The reason is that panel data modelling can contain more information, more variability, and more efficiency than pure time series data or cross-sectional data. In addition, the synthetic control method is also introduced to construct a counterfactual framework, so that the trade impact of the exchange rate reform can be presented quantitatively (Mniatem, 2018; Glaa et al., 2014; Taghipour and Frayret, 2011 & 2013).

3. The Influence of the Reform on China's Trade Balance

The reform of RMB exchange rate formation mechanism is a reform promoted by the People's Bank of China to transform the RMB exchange rate regime to a floating exchange rate regime. On January 1, 1994, China carried out a comprehensive reform of the foreign exchange system, which brought the official exchange rate into line with the market exchange rate and established a national standardized foreign exchange market. On July 21, 2005, the reform announced the implementation of a managed floating exchange rate system based on market supply and demand (Taghipour et Frayet, 2011; Taghipour et al., 2021; Yang et al., 2017; Tliche et al., 2021; Taghipour, 2018).

On August 11, 2015, the People's Bank of China started a new round of exchange rate reform. This reform has completely handed over the RMB exchange rate to the foreign exchange market, and the price is determined by the supply and demand of the market. However, on August 11, the RMB exchange rate depreciated by nearly 2% compared with the previous day. On August 13, the exchange rate was 6.401, depreciating by 4.66% compared with August 10.

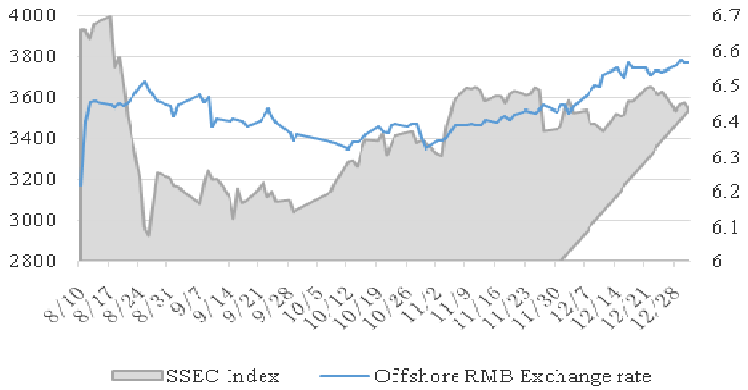

Figure1 SSEC Index and Offshore RMB Exchange Rate from July 1 to December 31, 2015

Data Sources: The People's Bank of China

It can be seen from figure 1 that the offshore RMB exchange rate against the US dollar continued to depreciate after "8.11 exchange rate reform". Three days after, the People's Bank of China stopped this reform, began to intervene in the foreign exchange market to stabilize the RMB exchange rate. From the SSEC Index trend in figure 1, we can see that after the exchange rate reform, there have been two large-scale declines in China's stock market. The SSEC Index once fell from a high of 3993 points to 2900 points, resulting in a total loss of nearly 20 trillion yuan in stock market value.

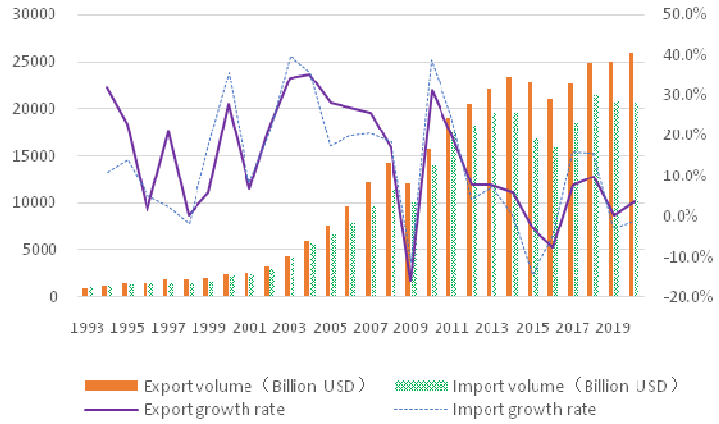

Figure 2 China's Import and Export Volume and Growth Rate from 1993 to 2020
Data Source: UNCTAD Database

From the perspective of the growth rate of China's imports and exports. As can be seen from figure 2, after the reform in 1994, China's import and export growth rate were basically positive. After the 2005reform, the growth rate of China's imports is higher than before. Although the global financial crisis in 2008 caused a sharp decline in the growth rate of China's imports and exports in 2009, the growth rate rose rapidly in 2010. But after the "8.11 exchange rate reform" in 2015, the growth rate weakened in 2015 and 2016, and then accelerated in 2017, with imports significantly faster than exports.

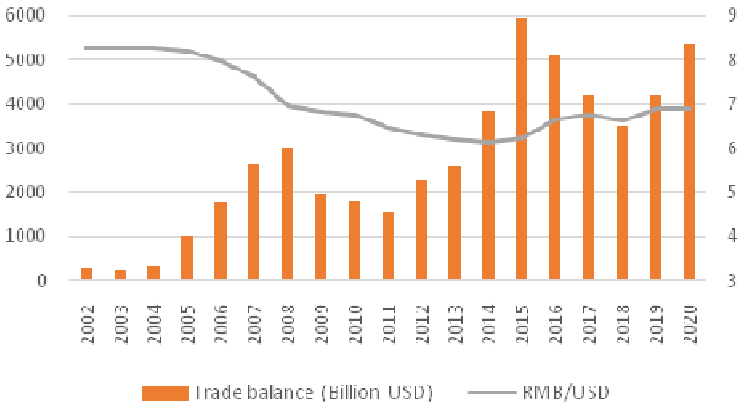

Figure 3 China's Trade Balance and RMB Exchange Rate from 2002 to 2020
Data Sources: The People's Bank of China

To observe the impact of the reform of RMB exchange rate formation mechanism on China's foreign trade from the perspective of trade balance. Figure 3 shows the changes in the RMB exchange rate and China's trade balance. Before 2005, the RMB actually adopted the exchange rate system pegged to the US dollar, so the RMB exchange rate remained basically stable at

this stage. And China's trade balance has been relatively stable and shows a small trade surplus before 2005.

After the RMB exchange rate system in 2005, the RMB exchange rate began to appreciate obviously from 2005 to 2008. According to the traditional balance of payments theory, a country's currency appreciation will lead to a decrease in its international trade balance, but China's trade surplus has shown a trend of rapid growth since 2005. In 2005, China's trade balance increased by 217.76% compared with 2004. After the devaluation of the RMB exchange rate caused by the exchange rate reform on August 11 in 2015, China's trade balance continued to decrease from 2015 to 2017, and did not begin to increase until the exchange rate showed a trend of depreciation again after 2018.

Combined with the above descriptive analysis, we can find that the relationship between the level of RMB exchange rate and the changes of China's trade balance is more complex. It is difficult to analyze the accurate relationship between them according to the classical theory and changing trends, which should be further verified with the help of empirical model.

4. Empirical Research

This section will first use the dynamic panel data model to test the relationship between RMB exchange rate and China's trade balance. And then we use the synthetic analysis method to discuss the impact of the "8.11 exchange rate reform" on China's export trade. So that the two empirical results can complement each other in analyzing the impact of the reform on China's trade balance.

4.1 Panel Model

In the empirical study of import and export trade, the existing studies mainly use the imperfectionist models. According to the model, domestic imports can't completely replace domestic goods, and domestic export products can't completely replace the domestic goods of other countries. It can be assumed that a country's import trade volume is a function of its gross domestic product (GDP), import price (P_m), domestic commodity price (P_d) and exchange rate (R). The export trade volume of a country is a function of the income level of the trading country (GDP'), the export price of its own goods (P_x), the export commodity price of the trading country (P_x') and the exchange rate R. The formula can be expressed as:

$$D_m = D_m(GDP, P_m, P_d, R) \quad (1)$$

$$D_X = D_X(GDP', P_X, P_x', R) \quad (2)$$

In the formula, D_m represents import demand and D_x represents export volume. In order to simplify the calculation, this paper assumes that the domestic commodity prices and the export prices of domestic goods are equal to the general price level of their own country, that isP_d=P_X=CPI, so asP_m= P_x'=CPI'. Therefore, the above expression (1) (2) can be expressed as:

$$D_m = D_m(GDP, CPI', CPI, R) \quad (3)$$

$$D_X = D_X(GDP', CPI, CPI', R) \quad (4)$$

The trade balance equation can be obtained by combining the above two formulas (3) (4). This paper constructs the following empirical model with reference to the research of Qian and Guoqiang (2005), and Dingyu and Cong (2016).

$$Y_{i,t} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 R_{i,t} + \beta_3 GDP'_{i,t}/GDP_t + \beta_4 CPI'_{i,t}/CPI_t + \varepsilon_{i,t} \quad (5)$$

In order to eliminate the possible heteroscedasticity of each variable data, all the data will be taken as the natural logarithm to analyze the elasticity coefficient of the impact. With $gdp_{i,t}$ for $GDP'_{i,t}/GDP_t$, $cpi_{i,t}$ for $CPI'_{i,t}/CPI_t$. Formula (5) can be rewritten as follows:

$$lny_{i,t} = \beta_0 + \beta_1 lny_{i,t-1} + \beta_2 lnr_{i,t} + \beta_3 lngdp_{i,t} + \beta_4 lncpi_{i,t} + \varepsilon_{i,t} \quad (6)$$

This paper selects the annual data of from 2002 to 2019 according to the ranking of China's foreign exports in 2019. In order to enrich the data range to cover five continents, New Zealand is selected in Oceania; Chile is selected in Latin American countries, and South Africa in Africa. These three countries together with the United States, Japan, South Korea, Germany, Australia, Vietnam, Malaysia, Brazil, the Russian Federation, India, Singapore, Thailand, the United Kingdom, the Netherlands, Indonesia, Canada, France, Italy, the Philippines constitute a sample section of 22 countries.

The explained variables are selected as the trade balance between those countries and China, represented by Y. In order to facilitate logarithmic processing, the trade balance is calculated by dividing exports by imports. The source of data is the Chinese National Bureau of Statistics. The explanatory variables are as follows. The first-period lag value of Y, to reflect the continuity of trade. The annual average exchange rate of RMB to 22 sample countries, using the direct pricing method, expressed as R. The data source is the Bank for International Settlements. The CPI selects the consumer price index of China and trading partner countries, the data source is the World Bank database, with 2010 = 100 as the base period. The GDP selects the gross domestic product of 22 trading partners and China, the data source is the UNCTAD database, in millions of US dollars.

Table 1 Statistical Description of Variables and Data

Variable		Mean value	Standard Deviation	Minimum Value	Maximum Value	Number of Samples
Explained variable	Y (Trade balance between China & other countries)	1.525569	1.547751	.3243348	8.841208	396

Explanatory variable	R (Annual Average Exchange Rate of RMB)	3.6907	3.853551	0.0002879	15.22272	396
Control variable	GDP (Gross Domestic Product)	.4009878	.8489205	.0030476	7.486311	396
	CPI (Consumer Price Index)	.9989381	.1273745	.5638372	1.421129	396

Before the empirical test, the unit root test of the variable is carried out to ensure the validity of the results. Levin-Lin-Chu test and Fisher-ADF test are used in this paper, and the results are shown in Table 2. All variables pass the significance test under 5%, means that the panel is stable.

Table 2 Variable Unit Root Test

Variable	Levin-Lin-Chu		Fisher-ADF	
	Statistical Value	P Value	Statistical Value	P Value
lny	-2.3755	0.0088	6.0848	0.0000
lnr	-4.8755	0.0000	4.8625	0.0000
lngdp	-4.4446	0.0000	3.7177	0.0001
lncpi	-1.7302	0.0418	5.9374	0.0000

Data Source: Collated according to the running results of stata15

Table 3 Empirical Results of SYS-GMM

Variable	Coefficient	P Value	Z Value
L.lny	0.909	0.000***	9.00
lnr	0.138	0.041**	0.15
lngdp	0.042	0.000***	0.44
lncpi	0.016	0.103	0.04
_cons	0.115	0.079*	0.65
AR (1)	-	0.0559	-
AR (2)	-	0.0150	-
Sargan	-	1	-

Note: *, * * and * * *represent significant at 10%, 5% and 1% levels.

The results are shown in Table 3. According to the empirical results, it can be concluded that: First, the lag first-order coefficient of Y is positive, and it has passed the significance test of 1%, indicating that the international trade relations between China and its trading partners have a good continuity. It shows that the stable development of bilateral relations has a good promotion and continuity to China's economic development.

Second, the coefficient of R is significantly positive at the confidence level of 1%, which means that if the RMB exchange rate appreciates, it will reduce China's trade balance. The empirical

results show that the relative appreciation of the RMB will improve the imbalance of China's trade balance.

Third, a significant positive GDP at 1% confidence level indicates that GDP has a positive impact on the trade balance. This shows that when the market size and income level of trading partners increase, it can promote the import demand of trading partners for Chinese goods.

Fourth, the coefficient symbol of the relative price level variable is positive, indicating that when the foreign price level becomes relatively high, China's export trade volume will increase relatively. However, the variable of price level did not pass the significance test of 10%, which shows that there are obstacles to the price effect in the transmission mechanism.

4.2 Synthetic Control Method

The synthetic control method is usually used to evaluate the impact of events or the implementation effect of policies. The main purpose of this empirical study is to explore the impact of the "8.11 Exchange rate Reform" on China's foreign trade in 2015. Taking 2015 as the time point of occurrence of the policy, the scope of the selected countries follows the countries used in the previous section, but Russia, which reformed the exchange rate formation mechanism in 2014, is excluded. In order to have a better analyze of empirical results, in this section, the explained variable selected is the export trade volume, and the other control variables are exchange rate, the total imports, total import and export trade, GDP, CPI, and the proportion of exports in total trade.

With reference to the empirical model of Abadie et al. (2010), the synthetic control method selected in this paper is basically set as follows. Suppose there are K+1 observable sample of trading partners, the observation period is $t \in T$, T_0 represents the period before the reform of the exchange rate formation mechanism, and T_1 represents the observation period after the reform of the exchange rate formation mechanism, T = T0 + T1. Country 1 is China, and countries 2 to K are the control group, representing other countries that have not undergone exchange rate formation mechanism reform during 2003-2019. R_{kt} represent that in the absence of policy intervention, the export trade volume of the Kth country in the t period. R_{kt}^{I} represents the export trade volume of the country K that has carried out the exchange rate system reform at t time point, and R_{kt}^{N}represents the export trade volume of the country K that has not carried out the exchange rate system reform at t time point. When $t \in T_0$, $R_{kt}^{I} = R_{kt}^{N}$. When $t \in T_1$, the influence of exchange rate formation mechanism, reform on the export trade volume of country K at t time point can be expressed as: $Y_{kt}=R_{kt}^{I} - R_{kt}^{N}$, $t \in T_1$. So it can be concluded that the impact of the reform of RMB exchange rate formation mechanism on China's export trade volume is $Y_{1t}=R_{1t}^{I} - R_{1t}^{N}$, $t \in T_1$. The main purpose of this section is to synthesize $R_{1t}^{N*}$to simulate China's export trade without the "8.11 exchange rate reform" in 2015.

Virtual China is synthesized by using the synthesis control method in stata15. Table 4 below shows the country weights of the control groups that make up virtual China. The comparison of the relevant variables between the virtual China synthesized by the four countries through the synthetic control method and the actual China from 2003 to 2019 is shown in Table 5. It can be seen from the table that there is a small difference between the real China data and the synthesized China data. This shows that the China synthesized by these four countries can better fit the situation of real China from 2003 to 2019.

Table 4 Weight Composition of Synthetic Virtual China

Country	Germany	United States	Japan	South Korea
Weight	0.421	0.295	0.175	0.109

Table 5 Variable Fitting by Synthetic Control Method in 2003-2019

Variable	Real China	Synthetic China
exchange rate	1.962955	1.708215
Total import volume	13.88231	13.87745
Total trade volume	14.65134	14.63735
GDP	15.31698	15.19291
Inflation rate	4.571151	4.58479
Exports/Total trade	.535	.5294108
Export volume in 2004	12.99049	13.42135
Export volume in 2009	13.99917	13.89117
Export volume in 2014	14.66664	14.64997

After determining the weight of synthetic China, the trajectory of the change of export trade volume between synthetic China and real China is shown in figure 4.In figure 4, the vertical dotted line represents the 2015 policy node. The left side of the vertical dotted line is before the "8.11 exchange rate reform" in 2015, and the right side is after the reform. It can be seen from figure 4 that the change trajectory of export trade volume between synthetic China and real China from 2003 to 2015 is basically the same, which shows that synthetic China better simulates the export trade level of real China. Comparing the export data from 2015 to 2019, it can be concluded that the average export value of China without the "8.11 exchange rate reform" is 1.33% higher than the actual value over the past four years.

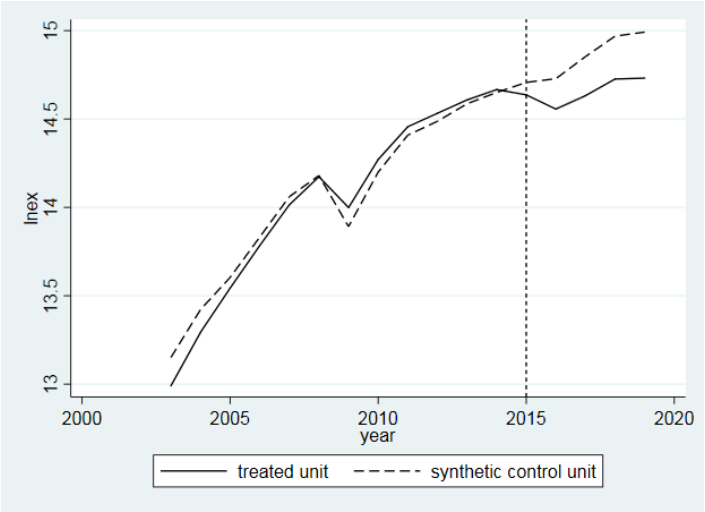

Figure 4 China and Synthetic China Export Trend Chart

In order to ensure the accuracy and robustness of the results, the placebo test should be used to exclude the contingency of the empirical results. Learn from Abadie et al. (2010), in this section, the placebo test selects two countries, one is Germany, which accounts for the largest weight in synthetic China, which means that among all the sample countries, its characteristics are similar to China in all aspects of the indicators. Another one is Italy, which has zero weight in the composite China, indicates that there is no obvious commonness between the characteristics of the country and China, so it is more convincing to take these two countries as the treatment groups to test the effect of the policy. The placebo test results are shown in figure 5, with Germany on the left and Italy on the right.

It can be seen from figure 5 that the total export volume of Germany and Italy has not shown the same trend as that of China after 2015, and the composite export volume of the two countries has always changed along the trend of the actual trade volume. And there is no obvious change before and after the time point, and the test proves that the result of synthetic China is valid.

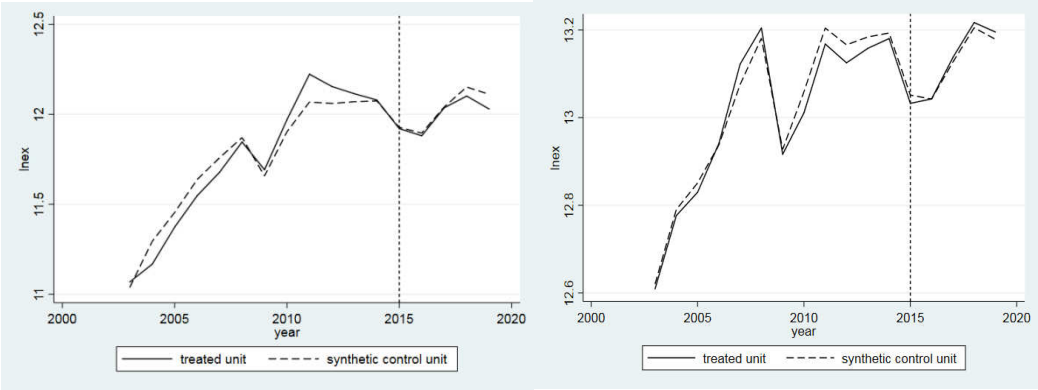

Figure 5 Real Germany, Italy and Synthetic Germany, Italy Export Trend Chart

5. Conclusions and Suggestions

Through empirical research, this paper finds that the relationship between RMB exchange rate and China's trade balance accords with the basic theory of balance of payments. The exchange rate reform of August 11 in 2015 had a negative impact on China's export trade. The average decline in export trade volume from 2015 to 2019 is 1.33%, and the downward trend is continuing to a certain extent. Therefore, it is very important to realize the smooth transition of the RMB exchange rate regime to free floating exchange rate regime.

This paper puts forward the following three countermeasures and suggestions: First, steadily promote the reform of RMB exchange rate formation mechanism, establish a reasonable reform system, and maintain the stability of RMB exchange rate in the process of transition. Second, China should continue to promote the negotiation of multilateral economic and trade agreements, such as Belt and Road Initiative and RCEP (Regional Comprehensive Economic Partnership), to reduce China's trade dependence on Europe and the United States. Third, expand the scale of China's import trade, balance China's trade deficitand promote the coordinated development of internal and external circulation.

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Demand Forecasting of Vaccines Using Intuitionistic Fuzzy Time Series Method

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Abstract

Postulating the demand for immunization vaccines is vital in maintaining the stocks in a healthcare facility. In the present scenario, the forecasting of immunization vaccines depends upon the obsoleted past data and outdated forecasting techniques. These outdated forecasting methods provide little understanding about the estimation of immunization vaccines, which leads to incorrect vaccine stock levelling and results in shortages or even vaccine expiration. Therefore, to eliminate this problem, advanced forecasting techniques should be adopted with relevant past data so that forecasting can be done accurately and precisely. Therefore, in this study, the demand forecasting of immunization vaccines for the rural areas of the state of Jharkhand is done using the Intuitionistic Fuzzy set (IFS) technique, providing the data form the government hospital of Jharkhand. The objective of this study is to test the applicability of IFS (Intuitionistic Fuzzy logic) technique in the demand forecasting of immunization vaccine for the rural areas of Jharkhand. This kind of study for the state of Jharkhand has never been conducted before in any literature work. The results obtained after forecasting has been tested under various error techniques such as MAD (Mean Absolute Deviation), RSME (Root Mean Square Error), MAPE (Mean Absolute Percentage Error), and AFER (Average Forecasting Error Rate). The output of the errors deviation such as MAD, RSME, MAPE and AFER came out to be 2.06, 9.14, 1.26% and 2.06. Hence, the Intuitionistic Fuzzy Logic (IFS) technique can be adopted to forecast immunization vaccines in rural areas of Jharkhand. This study can help increase the coverage of immunization vaccines in rural parts of Jharkhand and also helps in decreasing the costs associated with the immunization program, such as transportation, man, power and machine.

Keywords: *Demand Forecasting, Intuitionistic Fuzzy Logic, Child Immunization, Vaccine, Rural Healthcare, Time Series.*

1. Introduction

The vaccine is considered to be an important life-saving drug in healthcare(Orenstein & Ahmed, 2017). It not only saves life but so provides economic benefits. A study conducted over 94 countries across the globe found that investing $34 million in immunization programs would help reduce the cost by $1.53 trillion incurred due to broad illness(Ozawa et al., 2016).Increasing the coverage of immunization is an important goal for countries all over the

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world. As per MacDonald et al., (2020), the global vaccine action plan has developed a framework to prevent millions of death by 2020 which occurred due to the coverage limits of the vaccine.

One of the important challenges associated with this goal is an accurate demand forecasting of vaccines because underestimation of the vaccine may lead to shortages, and overestimation leads to wastage, which increases the overall cost. The forecasting of vaccines mainly depends upon two categories. These are (1) routine data collection, stock level changes entered by health workers, and extrapolation of past data.(2) population-related data of pregnant women and childbirth, age-based vaccination, an appropriate forecasting model. However, as per the studies from past researchers, the demand forecasting of vaccines is generally inaccurate, and there is a large scope of improvement in its(Patel et al., 2016)(Lydon et al., 2017). The major inaccuracy in forecasting is due to the use of the uni-dimensional forecasting model, which does not relate to the multidimensional nature of the problem associated with forecasting, such as easiness in accessing all the healthcare facilities' attitudes of the people towards vaccination. These challenges can be overcome by using real-time data from the healthcare facility and by using multi-dimensional expert system mechanism for forecasting, which not only uses the available data, but also uses other parameters such as population of data sets of that areas.

Therefore, to address this problem, this paper uses advanced forecasting technique that is intuitionistic fuzzy time series method (Rogers, 2002). It is an effective tool for estimating real value function, introduced by Atanassov in the 80s(Atanassov, 2016). The intuitionistic fuzzy sets (IFSs)is a generalized form of Fuzzy sets used for forecasting. IFSs further classifies the fuzzy sets into membership, non-membership and non-determinacy (hesitancy) functions and helps in classification of data. .

1.1. Problem Definition

There was a need for this type of advanced forecasting technique in this region because in Jharkhand, the majority of the population lives in rural areas(census, 2011) with poor connectivity and transportation network. Here the people are not knowledgeable enough to understand the advantages of immunization vaccines for their children. Therefore they show less interest in getting their child vaccinated. Hence to get these children vaccinated, the government sends their volunteers for the vaccination drive. But in this concern, if any kind of misinformation occurs regarding the population density to be vaccinated, then in that case the cost of vaccination drive becomes more expensive than anticipated. The majority of cost occurs due to transportation expenses as they have to make certain trips for a particular location if shortages occur. In contrast, if there is any surplus of the vaccine in a particular area, then there is a chance that it may get expired or deteriorate if not transported quickly to any other places or preserved nicely. So there is a need for proper demand forecasting to remove these problems.

1.2. Research Questions

Q1: How effective is the IFS (intuitionistic fuzzy set) technique in demand forecasting of immunization vaccine?

Q2: Is the IFS (intuitionistic fuzzy set) technique good for demand forecasting when there is a limited amount of data followed by ambiguity?

Q3: How the demand forecasting technique would help maximize the coverage of immunization vaccines in the remote and rural areas of Jharkhand?

1.3. Research Objectives

- To collect the past data of immunization vaccine from the government hospital of Jharkhand.
- To apply the IFS (intuitionistic fuzzy set) technique to the data collected from the government hospital of Jharkhand and make demand forecasting.
- To compare the actual and forecasted data and determine the error differences.
- To suggest some managerial implications about vaccination coverage.

This paper is organized as follows; section 2 presents the literature review based on the immunization issues. Methodology is discussed in section 3. Section 4 describes about fuzzy sets and intuitionistic fuzzy sets followed by a numerical example in section 5, managerial implications is provided in section 6and further the paper is summarized with concluding remarks.

2. Literature Review

Immunization is a strong and cost-effective tool in preventing diseases. Immunization is very important for an child because it protects them from serious illness such as TB(tuberculosis), pertussis, measles, tetanus, diphtheria and poliomyelitis. Despite the years of advancements in a medical facility, the child still gets virulent diseases due to inequality in vaccine coverage and acceptance. Also, the burden of delay in vaccination adds serious complications to it.

The literature survey methodology is as follows. The section 2.1 will provide the idea about the issues related to immunization in developing nations such as low and middle income countries. The section 2.2 will provide the status of the immunization program in India. This section will provide the insights about vaccination coverage in India and the how much percentage of children are still deprived from immunization program in India. Further the section 2.3 delivers the knowledge about the tools and techniques used for demand forecasting. Considering the issues of child immunization and vaccination in the country.

2.1. Issues Related to Vaccination in Developing Countries

The immunization programme is very important part of a country because it helps reduce two to three million deaths per year caused due to in-immunization(WHO, 2017). However, nearly ten percent of children worldwide remained un-immunized in 2016, accounting for 19.5 million infants who were deprived of vaccination that year. These are generally from low and

middle-income countries (LMIC). There are specific issues and challenges this LMIC faces. These are, ***Limited resources***: Low-income countries have very limited healthcare resources such as healthcare staff, storage capacity and transportation. Due to this, the, immunization coverage gets affected (Chen et al., 2014)(Lee et al., 2016). ***Vaccine wastage***: Vaccine wastage is very common thing in low-income counties. The wastage of vaccines generally occurs due to unreliable storage and transportation and improper inventory management. The inventory management of these vaccines is very important because overstocking of these vaccines results in the expiration and understocking of these results in storage and hence missing the immunization opportunities(Guichard et al., 2010)(Vickers, 2017)..***Data availability***: Another challenge faced in this issue by low and middle-income counties is data availability. The actual data is not often available; the viable data are mainly paper-based with full of ambiguity (Brooks, Habimana, & Huckerby, 2017).

2.2. Status of Immunization vaccine in India

In recent times in India, due to the proper distribution system of immunization vaccines, a steep decline has been shown in under-five mortality rate that is from 93 mortality per 1000 children in 1990s to 41 death per 1000 live birth in 2016. India has remarkably improved in declining the mortality rate of children under five years of age from 126 in the 1990s to 43 death in 2016 per 1000 children. This accounts to a 4.1% reduction annually(Lucia Hug, David Sharrow, 2017). In India, 26 million children get vaccinated annually(WHO, 2016). India has remarkably improved its immunization coverage rate in the last two decades. For example, in 1992-93, the coverage of child vaccination was 35 per cent, which further improved and reached 42 per cent in 1998-1999 as well as 44 per cent in 2005 and 62 per cent in 2016(National Family Health Survey (NFHS-4), 2016)(National Family Health Survey (NFHS-4), 2007). Although the government has made remarkable improvements over the past two decades but there still exists some discrepancy in vaccine coverage rate among socioeconomic levels (National Family Health Survey (NFHS-4), 2016).

Therefore to maximize the coverage rate, the Indian government launched certain programs, such as universal immunization program in 1985, Expanded Programme on immunization in 1978, (Aruna Rastogi, 2018). Apart from that government of India has also collaborated with international volunteers such as the global alliance for vaccination and immunisation(GAVI) in the year 2014 under National Rural and Health Mission(NRHM) to eradicate the immunization coverage gap in India(Nossal, 2000). Further, India also launched Mission INDRDHANUSH, intending to immunize children who live in remote and difficult-to-reach areas.

Despite such devoted programs on child immunization, a significant number of children remains unimmunized, and these numbers have become stagnant since 2005-2006(National Family Health Survey (NFHS-4), 1995)(National & Family Health Survey (NFHS-2), 2000). Certain undocumented disparities existsconcerning to immunization at remote areas in India.

Thus some recommended research work should be conducted to examine the disparity of childhood immunization coverage in India.

2.3. Forecasting Technique used in Demand Forecasting of Immunization Vaccine

The forecasting is very important to determine the demand of the vaccine in a particular region or area. Demand forecasting not only helps strengthen the nation but also boost the country's economy. In this regard several researchers have bestowed their effort, such as Sahisnu et al, (2020) in this paper they have used the ARIMA model to determine the vaccine stock level so that no excess stock or shoratges occurs. de Figueiredo et al.,(2016) collected the past 30 years data, that is from 1980 to 2010 and used the Gaussian process regression to forecast vaccine coverage. These are some basic forecasting models used by the researchers, but they have certain limitations. This model doesn't consider the factors like, behaviour of the people towards the immunizations and the number of ambiguity present in the data. These two factors should also be considered while doing the demand forecasting. Therefore some advanced machine learning techniques have been used for forecasting such as Alegado et al,(2020) they used Auto-Regressive Integrated Moving Average (ARIMA) model along with Multilayer Perceptron Neural Network (MLPNN) to forecast the demand of vaccine to avoid shortages and excess supply of immunization vaccines. Hariharan et al., (2020)used the random forest regressor method to do the demand forecasting of immunization vaccines in Tanzania.

2.4. Literature Gap

After the literature review, it is found that the demand forecasting of immunization vaccines is very important for the growth of developing countries like India. Therefore it is important to make an cost-effective demand forecasting solutions for the problems faced by India so that immunization coverage can be improved further. Among the literature works present, no such research was found where the demand forecasting of the immunization vaccine has been done for the rural areas of Jharkhand using advanced forecasting techniques such as intuitionistic fuzzy set (IFS). Therefore in this paper the IFS has been used to forecast the demand of immunization vaccines using the past data's from the healthcare facility of Jharkhand.

3. Methodology

To forecast the demand appropriately, Intuitionistic fuzzy set (IFS) technique is used. The process description and theory is described below as:

Fuzzy Set and Intuitionistic Fuzzy Set

a) Fuzzy set:-This was introduced Zadeh in 1965(Zadeh, Introduction, & Navy, 1965). HereX is constant set, which isdefined as $A = \{< x, \mu_{(A)}(x) > | x \epsilon X\}$.where μ_A is the membership function of the fuzzy set A.$\mu_{(A)}: X \rightarrow [0,1]$. $\mu_{(A)}(x)$denotes the membership function of x in A.Where A iscalculated by

$$A_i = \frac{\mu_{A_i}(x)}{x_1} + \frac{\mu_{A_i}(x_2)}{x_2} + \cdots \ldots \ldots \ldots \ldots + \frac{\mu_{A_i}(x_n)}{x_n} \quad (1)$$

b) Intuitionistic fuzzy set:-This was introduced by Atanassov in 1980s (Atanassov, 2016). It is an generalised concept of fuzzy set, given by:

$$I = \{< x, \mu_I(x), v_I(x) > | \forall x \epsilon X\} \quad (2)$$

Where $\mu_I: X \rightarrow [0,1]$ →Defines degree of membership

$v_I: X \rightarrow [0,1]$ →Defines degree of non-membership

$\pi_I(x) = 1 - \mu_I(x) - v_I(x) \rightarrow$ Defines degree of non-determinacy (3)

$$0 < \mu_I(x) + v_I(x) < 1$$

a) Intuitionistic Fuzzy Sets Cartesian product

Definition 1:-

If $P = \{< \mu_p(x), v_p(x) > | x \epsilon U_1\}$

$Q = \{< \mu_Q(y), v_Q(y) > | y \epsilon U_2\}$

Then the product of $P \times Q$ is

$$P \times Q = \{< (x,y), \min\left(\mu_p(x), \mu_Q(y)\right) \max\left(v_P(x), v_Q(y)\right) > | x \epsilon U_1, y \epsilon U2\} \quad (4)$$

Definition 2:-

Let IFS(x, y) isthe set of IFSs in x × y. Suppose R and S be the sets where R,S ∈IFS(x,y),Therefore the composition and union relation of R and S is.

$$R \cup S = \{< (x,y), \max\left(\mu_R(x,y), \mu_S(x,y)\right) . \min\left(v_R(x,y), v_S(x,y)\right) > | (x,y) \epsilon (X,Y)\} \quad (5)$$

$$RoS = \{< (x,y), \max\left(\min\left(\mu_R(x,y), \mu_S(x,y)\right) \min(\max\left(v_R(x,y), v_S(x,y)\right)\right) > | (x,y) \epsilon (X \times Y)\} \quad (6)$$

b) Intuitionistic Fuzzy time series

Definition 1: Let Y (t), (t=0, 1,2,3.....) is the universe of discourse and $I_f(t)$, $(f = 1,2,3 \ldots \ldots)$ are the fuzzy sets describes the discourse (t). If Ψ(t) is the group of $I_f(t)$ then Ψ(t) describes the intuitionistic fuzzy time series on Y(t) at distinctive times, The value of Ψ(t) will be dissimilar at different time(t), and Y(t) can also be distintive at different times.

Definition 2:

If Ψ(t) is caused by many IFSs which is represented by $I_{f_1}, I_{f_2}, I_{f_3} \ldots \ldots I_{f_n} \rightarrow I_k$then the intuitionistic fuzzy relationship can be expressed by

$$I(t-n) = I_{f_1}, I(t-n+1) = I_{f_2}, \ldots \ldots \ldots \ldots \ldots \ldots \ldots I(t-1) = I_{f_n} \quad (7)$$

The equation 7 is called intuitionistic fuzzy time series for nth order.

4. Steps in Constructing Intuitionistic Fuzzy Sets

Step 1: Find the universe of discourse (U). Here U is described using 3 statistical terms: minimum value, maximum value and standard deviation (σ) for the given time series. $U = [D_{\min} - \sigma, D_{\max} + \sigma]$. Here $D_{\min}$ →minimum value of the time series data and $D_{\max}$ →maximum value of the time series data.

Step 2: Define the linguistic intervals. The universe of discourse U partitioned into n intervals using CPDA (cumulative probability distribution approach) method (Gangwar & Kumar, 2014). This step is divided as follows.

Define the upper bound (P_{UB}) and lower bound (P_{LB}) cumulative probability. Here i denotes linguistic value and n defines linguistic interval.

$$P_{LB}^{1} = 0$$

$$P_{LB}^{1} = \frac{2i-3}{2n}, (2 \le i \le 3) \quad (9)$$

$$P_{UB} = \frac{i}{n} \quad (10)$$

Step 3: To find the degree of membership. Draw the triangular fuzzy (Gangwar& Kumar, 2014) set with respect to number of intervals described in step 2 and apply the triangular membership to each interval of triangle fuzzy set.μ(x) is the membership function. Here 'a' denotes the lower bound, 'b' denotes the upper bound and 'm' denotes the midpoint of the universe of discourse.

$$\mu(x) = \begin{Bmatrix} 0, & if(x \le a) \\ \frac{x-a}{m-a}, & if(a \le x \le m) \\ \frac{b-x}{b-m}, & if(m \le x \le b) \\ 0 & if(x \ge b) \end{Bmatrix} \quad (12)$$

Step 4: Draw the IFS table and non-determinacy table. Apply the construction method of IFS (Burillo & Bustince, 1996) and draw a IFS table corresponding to the triangular fuzzy sets of P_n.

Step5: Fuzzify the time series data according to their membership, non-membership and degree of hesitancy. For example I_1 (intuitionistic fuzzy set) can be written as< data, membership, on-membership, hesitancy degree>

Step 6: Make the fuzzy logical relationship group (Gangwar & Kumar, 2014). The fuzzy logical relationship is established which is denoted by$P_i \rightarrow P_j$.Where P_i denotes the current state that is N^{th} month and P_j denotes the next month $(N+1)^{th}$ month.

Step 7: Do the linguistic forecasting. Using the equation (13)

$$P_i = \frac{\mu_{P_i}(x_1)}{x_1} + \frac{\mu_{P_i}(x_2)}{x_2} + \frac{\mu_{P_i}(x_3)}{x_3} + \cdots \frac{\mu_{P_n}(x_n)}{x_n} \quad (13)$$

Where $\mu_{P_n}(x)$ denotes the degree of membership of x in fuzzy set and x denotes the respective value from the data.

Step 8: Do the numerical forecasting. Defuzzify the linguistic forecasting's by using weighted average formula (Gangwar & Kumar, 2014) shown in equation (14).

$$\text{Numerical forecasting} = \frac{\sum_{i=1}^{n}(\mu_i - \nu_i)l_i}{\sum_{i=1}^{n}(\mu_i - \nu_i)} = \frac{\sum_{i=1}^{n} W_i l_i}{\sum_{i=1}^{n} W_i} \quad (14)$$

$\mu_i \rightarrow$ membership degree

$\nu_i \rightarrow$ non − membership degree

$W_i = (\mu_i - \nu_i)$, $l_i \rightarrow$ Midpoint of the interval.

Step 9: Calculate the forecasting errors. Now find out the % errors.

$$\text{MAD} = \frac{\sum |\text{Actual-Forecasting}|}{n} \quad (15)$$

$$\text{MAPE} = \left(\frac{1}{n}\sum \frac{|\text{Actual-Forecast}|}{|\text{Actual}|}\right) \times 100 \quad (16)$$

$$\text{Average forecasting error rate} = \frac{\text{Sum of forecasting error}}{\text{number of errors}} \quad (17)$$

5. Forecasting the vaccination demand as per the proposed model

Demand data of a vaccine (BCG) taken from government hospital in the state of Jharkhand is given as in Table 1. To forecast the demand the reference demand data should follow the average crude birth rate of the particular region, i.e.0.9909, hence reference demand data has been obtained by multiplying the raw data with average crude birth rate as given in Table 1.

Step 1: The demand data of BCG vaccine is shown in table 1.Table 1will be used to find D_{min}andD_{max}.as well as universe of discourse.

Table 1 Actual Demand Data

Sl. No	Month	Actual Data	Actual Multiplied Data
1 (A)	January	243	240.7889
2 (B)	February	159	157.5533
3 (C)	March	182	180.3438
4 (D)	April	203	201.1527
5 (E)	May	173	171.4257
6 (F)	June	179	177.3711
7 (G)	July	172	170.4348
8 (H)	August	183	181.3347
9 (I)	September	183	181.3347
10 (J)	October	183	181.3347
11 (K)	November	195	193.2255
12 (L)	December	211	209.0799

Step 2: The universe of discourse U, has been divided into six linguistic interval by using equation 9 and 10, shown in table 2.

Table 2 linguistic Intervals

Linguistic Value	Cumulative Probability		Universe of Discourse		
	P (lower bound)	P (upper bound)	Lower bound	Mid-point	Upper bound
μ_1	0	0.1667	116.089	141.4704	166.8517
μ_2	0.0833	0.333	158.2868	168.2096	178.1323
μ_3	0.25	0.50	173.1189	180.1169	187.115
μ_4	0.4167	0.6667	182.72	193.7998	196.0977
μ_5	0.583	0.8333	191.5019	199.4401	207.3783
μ_6	0.75	1	201.3202	229.7306	258.141

Step 3: From table 2, the triangular fuzzy sets will be constructed shown in figure 1, where P_1,P_2,P_3,P_4,P_5,P_6 represents the fuzzy set. The dots represents the degree of member of each data shown in table 1.

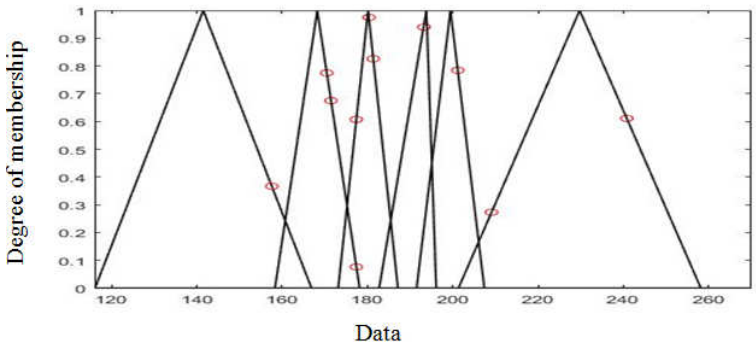

Figure 1: Triangular fuzzy sets

Step 4: Using the triangular fuzzy sets shown in figure 1,the membership degree, non-membership degree and degree of hesitancy (non-determinacy) is found out using equation 3.

Table 3 Degree of Membership

S.No	Month	Data	Degree of Membership
1	JAN	240.7889	0.611
2	FEB	157.5533	0.3668
3	MAR	180.3438	0.9748
4	APRIL	201.1527	0.7843
5	MAY	171.4257	0.675
6	JUNE	177.3711	0.6075,0.076
7	JULY	170.4348	0.775
8	AUG	181.3347	0.8259

9	SEPT	181.3347	0.8259
10	OCT	181.3347	0.8259
11	NOV	193.2255	0.94
12	DEC	209.0799	0.2731

Table 4 The Membership and Non –Membership Grade

Month	Data	I_1	I_2	I_3	I_4	I_5	I_6
JAN	240.7889	0	0	0	0	0	0.4482, 0.2854
FEB	157.5533	0.2691, 0.46466	0	0	0	0	0
MAR	180.3438	0	0	0.7152, 0.0185	0	0	0
APR	201.1527	0	0	0	0	0.5754, 0.1583	0
MAY	171.4257	0	0.4952, 0.2385	0	0	0	0
JUN	177.3711	0		0.4457, 0.28806	0.05576, 0.6780	0	0
JUL	170.4348	0	0.5686, 0.165173	0	0	0	0
AUG	181.3347	0	0	0.6059, 0.127827	0	0	0
SEP	181.3347	0	0	0.6059, 0.127827	0	0	0
OCT	181.3347	0	0	0.6059, 0.127827	0	0	0
NOV	193.2255	0	0	0	0.6896, 0.04412	0.1731, 0.610	0
DEC	209.0799	0	0	0	0	0	0.20037, 0.533417

The degree of hesitancy (non-determinacy) is calculated from table 4using equation 3.

Table 5 The Degree of Hesitancy and Non-Determinacy

Month	Data	I_1	I_2	I_3	I_4	I_5	I_6	Fuzzy sets
Jan	240.7889	1	1	1	1	1	0.2664	P_6
Feb	157.5533	0.26624	1	1	1	1	1	P_1
Mar	180.3438	1	1	0.2663	1	1	1	P_3

Apr	201.1527	1	1	1	1	0.2663	1	**P_5**
May	171.4257	1	0.2663	1	1	1	1	**P_2**
June	177.3711	1	1	0.2664	0.26624	1	1	**P_4**
July	170.4348	1	0.266227	1	1	1	1	**P_2**
Aug	181.3347	1	1	0.266273	1	1	1	**P_3**
Sept	181.3347	1	1	0.266273	1	1	1	**P_3**
Oct	181.3347	1	1	0.266273	1	1	1	**P_3**
Nov	193.2255	1	1	1	0.266288	0	1	**P_4**
Dec	209.0799	1	1	1	1	1	0.266218	**P_6**

Step 5: Some important explanation using fuzzification technique has been explained below.

Example 1: The actual demand for vaccine in the January 2018 was 240.7889 .this value lies in the interval μ_6 shown in table 2.therefore the intuitionistic fuzzy set I_1 =<240.7889, 0.4482, 0.2854> is constructed with the degree of hesitancy 0.2664 as shown in table 4 and 5.

Example 2: The actual demand for June 2018 is 177.3711 which lies in the interval μ_3 and μ_4 shown in table 2.Therefore it lies in two intuitionistic fuzzy sets I_3=<177.3711,0.4457,0.28806> and I_4 =<177.3711,0.05576,0.6780> shown in table 4.The degree of non-determinacy for I_3 and I_4 are 0.2664, 0.26624 as shown in table 5.Among these IFSs, the set with minimum degrees of non-determinacy will be chosen to do linguistic forecasting.

Step 6: In this we will try to establish fuzzy logical relationships using the table 5.

$P_6 \rightarrow P_1, P_1 \rightarrow P_3, P_3 \rightarrow P_5, P_5 \rightarrow P_2, P_2 \rightarrow P_4 P_4 \rightarrow P_2, P_2 \rightarrow P_3, P_3 \rightarrow P_3, P_3 \rightarrow P_3, P_3 \rightarrow P_4 P_4 \rightarrow P_6$

The fuzzy logical relationship group is established:-

$P_1 \rightarrow P_3$

$P_2 \rightarrow P_3$, $P_2 \rightarrow P_4$

$P_3 \rightarrow P_3$, $P_3 \rightarrow P_3$, $P_3 \rightarrow P_4$ $P_4 \rightarrow P_6$

$P_5 \rightarrow P_2$ $P_6 \rightarrow P_1$

Step 7: Do the linguistic forecasting of each data using equation 13:-

Table 6 Linguistic Forecasting Value

Month	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**
January	-	-	-	-	-	0.002537
February	0.002328	0	0	0	0	0
March	0	0	0.005405	0	0	0
April	0	0	0	0	0.003899	0
May	0	0.003935	0	0	0	0
June	0	0	0.003524	0.000428	0	0
July	0	0.004547	0	0	0	0

August	0	0	0.004554	0	0	0
September	0	0	0.004554	0	0	0
October	0	0	0,004554	0	0	0
November	0	0	0	0.004865	0	0
December	0	0	0	0	0	0.001306

Step 8: Do the Actual forecasting using weighted average formula as shown in the equation (14).

Table 7 Comparison between the Actual Data and the Forecasted Data

Sl no	Month	Actual data	Forecasted data
1	January	243	229.73
2	February	159	141.47
3	March	182	180.1169
4	April	203	199.44
5	May	173	168.2046
6	June	179	169.52
7	July	172	168.2096
8	August	183	180.1169
9	September	183	180.1169
10	October	183	180.1169
11	November	195	193.7998
12	December	211	229.73
MAD=2.06733			
MAPE=1.269169			
AFER=2.06733 RSME=9.14			

The errors such as MAD, MAPE and AFER has been found out by comparing the forecasted data with actual data and it values came out to be 2.06, 1.26 and 2.06 as shown in table 7. The errors came out to be satisfactory.

For the validation of this study the errors have been compared with the existing literature works of Bisht et al, (2018)and the results came out to be acceptable. Therefore the IFS techniques can be used by the government hospital of Jharkhand for doing the demand forecasting of immunization vaccines for the rural areas of Jharkhand

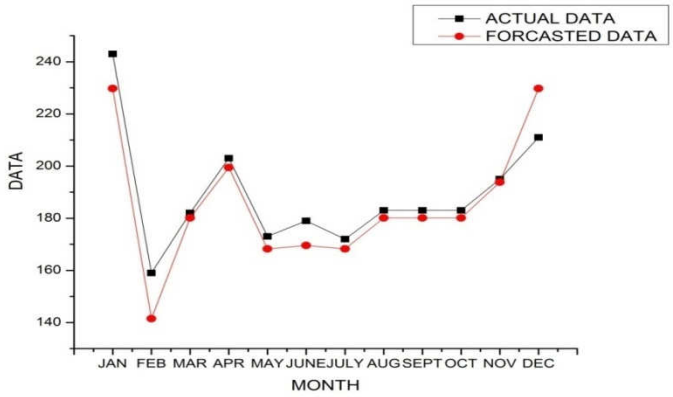

Figure 2 Forecasted vs Actual Representation

6. Managerial Implications

The certain managerial implications have been drawn after employing the IFS (Intuitionistic Fuzzy Set) technique in the government hospital of Jharkhand.

- As the errors have been calculated and it came out satisfactory. Therefore the IFS (Intuitionistic fuzzy set) can be used by the government hospital of Jharkhand for demand forecasting of immunization vaccines.
- As the errors were limited, it will help the transportation companies in making their routing more efficient and robust, which indirectly helps in more vaccination coverage.
- As the IFS (Intuitionistic fuzzy set) technique shows limited errors, therefore it can help in proper planning of man, power and machine so that the immunization coverage can be expanded and the overall cost can be decreased.

7. Conclusion

Improving the early childhood vaccination rate is important in ensuring good health for the infants living in India. A growing number of children are unvaccinated due to economic or social reason. Therefore this paper can help in bridging the demand-supply gap by getting appropriate demand forecasting of vaccines. Some of the forecasted data are above and below the actual data. This shows the unbias nature of the forecasted demand and the applicability of the IFS (Intuitionistic fuzzy set) technique. Further as the actual data's were limited, then also this technique can also generate demand forecasting data's with limited error's in it. This shows the robustness of IFS (Intuitionistic fuzzy set) technique. Additionally, this study helps answer the research questions in section 1.2. The Intuitionistic fuzzy set method had been used to forecast the demand of immunization vaccines for the certain period of time and the errors such as MAD, MAPE, AFER and RSME have been calculated as shown in table 7. The results show satisfactory and hence this technique is implementable with certain terms and conditions.

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GUIDELINES FOR AUTHORS

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