OPPORTUNITY OF BLOCKCHAIN TECHNOLOGY IN CONSTRUCTION SUPPLY CHAIN MANAGEMENT IN INDIA

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Management

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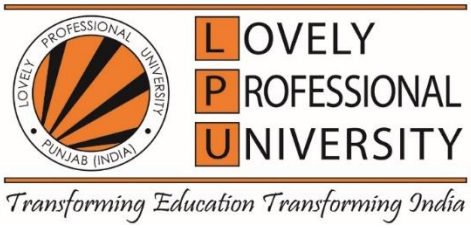

LOVELY PROFESSIONAL UNIVERSITY, PUNJAB

2022

DECLARATION

I, hereby declare that the presented work in the thesis entitled "Opportunity of Blockchain Technology in Construction Supply Chain Management in India" in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision Dr. Mohd Imran Khan, working as Assistant Professor, in the Department of Operations Management in Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

(Signature of Supervisor)

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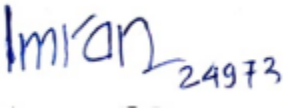
CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled "Opportunity of Blockchain Technology in Construction Supply Chain Management in India" submitted in fulfillment of the requirement for the reward of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Operations Management in Lovely Professional University, is a research work carried out by Prasanta Kumar Gupta, Registration No.41800886, is bonafide record of his original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.



(Signature of Supervisor)

Name of supervisor: Dr. Mohd Imran Khan

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University: Lovely Professional University

ABSTRACT

The theme of this research was conceptualized while working with Larsen & Toubro Construction as Head of Capital Procurement and Global Sourcing. Day to day challenges the supply chain faces resulting in time & cost overrun of construction projects and how can that be addressed utilizing digital technology were the genesis of this study.

Construction is the largest industry in the world and still is not performing as expected. The construction ecosystem represents 13 percent of global GDP, yet saw a miserable productivity growth of 1 percent year on year for the last two decades. Time and cost overrun is the norm and overall earnings before interests and taxes (EBIT) are only around 5 percent despite the presence of substantial risk in the business. A mixture of sustainability requirements, cost pressure, skills scarcity, innovative materials, industrial advancements, digitalization and a new entrant looks set to transform the value chain. McKinsey Global Institute indicated that the construction industry needs to progress and show ways in which it can change to enhance productivity by 50-60 percent and deliver US$ 1.6 trillion in a year in incremental overall value (McKinsey & Company Report, 2020).

In India, construction industry registered a growth of 8.1 percent of national GDP in FY 2021-2022. The sector is expected a steady growth at the rate of 6.2 percent during 2023-2026. As per industry forecast, Indian construction industry would reach US$ 1.4 Trillion by 2025 and would contribute to 13 percent of GDP by 2030. (Source https://www.indianmirror.com/indian-industries/2022/construction-2022.html).

In India construction sector is the second largest employer after agriculture. With upcoming and ongoing mega infrastructure projects like High-Speed Rail, Mumbai Trans Harbor Linc, Mega Airports, Smart Cities, 20 million Affordable Housing by 2022, Atal Mission for Urban Rejuvenation etc., the sector has got unrestricted opportunities. The unprecedented learning of the world during COVID-19 waves and dent in credibility of China, opened a new horizon of Foreign Direct Investments (FDI) to India. The announcement by Government of India welcoming 100 percent FDI in construction sector added additional impetus. COVID-19 first wave, taught India the concept New Normal, but dreadful second wave made India more resilient accepting the concept Work from Home (WFH) as a future normal. Many corporates adopted WFH as a permanent way forward for the activities which can be well managed from a distance without any negative impact on quality and employee engagement. This created

another opportunity to construction GIG- economy for renovation of houses crafting an office space at home.

About 57.5 million workers are associated with Indian construction industry, 50 percent of which belongs to informal sector. With the anticipated high pace investment in the sector, the number is expected to cross 71.4 million by 2030. India is capable of catering the increasing demand of construction workers, but quality remains an issue of concern. India ranked 70 out of 140 countries on global infrastructure quality competitive index. Source: taskforce report of National Infrastructure Pipeline 2019-2025 released by Nirmala Sitharaman, December 2019.

According to the latest report for August 2022 of Ministry of Statistics & Programme Implementation, Govt of India (Statista Research Department, 2022) which examines infrastructure projects of INR 150 crore and more. Among 1526 projects, 393 were reported having cost overruns and 647 projects fell under time overrun. Expenses incurred on those projects was Rs 13,60,645.94 crore till August 2022 (52.49 percent) against the total estimated costs of those 1526 projects were Rs 21,26,460.93 crore. Further, the anticipated completion costs are likely to be Rs 25,91,823.45 crore causing an overall cost overruns of 21.88 percent.

Logistics cost in India is 14percent of GDP compared to 8 percent in USA. As per NITI Aayog, if India achieves its goal of reducing logistics cost to 10percent, it can save INR 10,000 billion during 2022-2025.

Fast Tracking Freight in India-A Roadmap for Clean and Cost-effective Goods Transport (RMI India, 2021). Cargo Transportation plays a vital starring role in strengthening the economy of a nation. Owing to the soaring need for goods and services, freight transport demand in India has been increasing an approximate 5 percent rate since 2015 and is expected to increase rapidly over at least next few decades. Freight transport is a vital pillar of the Indian economy, but still it can have negative impacts like high logistics costs, increasing CO2 emissions and deteriorating air quality leading to bad public health.

India would be able to handle these negative impacts encashing the major opportunity areas like:

1. Utilising more of rail freight transport developing dedicated freight corridors

2. Augmenting truck usage

3. Increase the fleet of zero-emission vehicles, focussing more on green energy powered vehicles economy improvement technologies

NITI Aayog and RMI summarize solutions for the prospect areas cited above. These prospects would enable the freight transfer ecosystem in India to turn out to be more cost-effective, enhanced and disinfectant. Collectively, these prospects can unlock 10 gigatons of aggregate CO2 discharge savings by 2050. This would benefit India accomplish its goal of cutting the logistics costs from 14 percent to 10 percent of GDP. This will also reduce nitrogen oxide and particulate matter discharges by 35 percent and 28 percent respectively till 2050.

Opportunities are limitless in Indian construction industry and adequate resources are available, but without the right knowledge, skillset and technology adoption all these will end up as numbers only. Transfer of knowledge and development of skillset will improve employability in Indian construction sector, it also ensures construction quality and enhances sustainable construction ecosystem. India is predominantly a leading exporter of construction services in Middle East and Africa. With the enhanced knowledge and skillset improvement, India would be in a position to earn much more foreign currency with due respect.

Adoption of digital technology can drastically improve the productivity of construction workforce in many ways ensuring trust, transparency in very efficient way and make the construction SCM future ready. Success lies in the selection of digitalization tools/methods and implementation of the same across the organization with top-down approach, continuous measurement of the efficiency and prompt addressal of the modification needs.

"A relatively new technology that might meet these criteria is the Blockchain Technology", (Loop, 2018).

Blockchain Technology (BLT) is expected to grow USD 3 trillion (Tn) globally by 2024 and would cross USD 5 Tn by end of 2025. As per the report of IDC (International Data Corporation), Blockchain Technology would have a spent of SD 11.7 Bn in 2022, with a compounding annual growth rate (CAGR) of 73.2 percent. As high as 69 percent banks globally are piloting Blockchain in their function. This percentage in case of North American Banks is 90. The European banks are not left behind with a considerable amount of investment in this digital Technology progress to bring transparency in their banking process and address data security. Shortly, we would hardly find any bank in the globe without Blockchain Technology

and AI (Artificial Intelligence) supported processes. Banks and Financial institutions are saving around USD 12 Bn annually by embracing Blockchain Technology powered decentralized finance solutions.

As anticipated third largest construction market in the world by 2025, India needs to have future ready SCM, which includes provision of human and financial resources, circular economy (reduce, reuse and recycle), adequate cutting-edge Digital Technology (Blockchain Technology, Artificial Intelligence, Machine Learning, Robotic Process Automation etc.) to facilitate and establish internal SCM objectives that are crucial for enhancing SCM efficacy.

Therefore, to capitalize supply chain potentiality into reality, India needs to focus on triple bottom-line growth of construction sector with defined roadmap. Organizations need to invest in enabling infrastructure and adoption of Digital Technology. Digital Supply Chain has already gathered prominence in the industry and induction of digital technologies like Blockchain Technology in construction SCM is going to be a game changing proposition to any organizations in the sustainability driven world.

Governments are relentlessly trying for development of supply chain infrastructure and ecosystem in India, but responsible utilization of those facilities will be the key to success. A sustainable digital technology which is largely capable of making construction supply chain efficient enhancing transparency, traceability, cost effectiveness and care to ecology & economy is Blockchain Technology.

Based on the research problem, I identified the following five research objectives:

1. To identify areas where the blockchain provides the most value for construction supply chain management
2. To identify drivers, barriers, and risk to blockchain deployment within construction supply chains management.
3. To explore the factors influencing the deployment of smart contracts as well as their success indicators in Indian construction supply chain management.
4. To evaluate the impact of critical factors on effective implementation of smart contract in construction supply chain management.
5. To evaluate the effect of smart contracts on performance of the construction supply chain management.

Research method followed against each objective and outcome of those are depicted hereunder:
Objective 1: To identify areas where the blockchain provides the most value for construction supply chain management: Conducted virtual focused group discussion among 46 SCM professionals in construction sector , primarily identified 31 areas, further deliberated and considered top 15 areas where blockchain can provide the most value for construction supply chain.
Objective 2: To identify drivers, barriers, and risks to blockchain deployment within construction supply chain management: Based on the literature review and virtual focus group discussion, I initially identified 22 drivers, barriers, and risks to blockchain deployment. Further deliberated and considered the top 10 areas to identify drivers, barriers, and risks to blockchain deployment within construction supply chain management.
Objective 3: To explore the factors influencing the deployment of smart contracts as well as their success indicators in Indian construction supply chain management : Conducted 11 sustainable SCM workshops involving 165 suppliers/contractors to understand the influencing factors in smart contract deployment. Designed a model to define the success indicators of smart contract in SCM.

Objective 4: To evaluate the impact of critical factors on effective implementation of smart contract in construction supply chain management: Identified top 69 suppliers/contractors for survey to understand the critical factors in smart contract implementation. Carried out 3 workshops with them in December 2021, January 2022 & February 2022. Based on the identified factors, designed a structured questionnaire in consultation with my supervisor. Sent the questionnaire to 3 academicians & 3 industry experts for validation.

Objective 5: To evaluate the effect of smart contracts on performance of the construction supply chain management: Based on the identified KPIs of construction/project SCM and identified factors, designed a structured questionnaire in consultation with my supervisor Conducted pilot study with 3 academicians having expertise in digital supply chain and blockchain and 25 industry experts in construction industry. Modified eight questions and dropped two based on their feedback.
The following null hypothesis were tested during the research work:

- Hypothesis 1 (H1)- “Contract Management/Governance related” (CMR) critical factor will not affect the effective “implementation” (IS) of smart contract in construction supply chain.
- Hypothesis 2 (H2)- “Client Related” (CLR) critical factor will not affect the effective “implementation” (IS) of smart contract in construction supply chain.
- Hypothesis 3 (H3)- “Supplier Related” (SPR) critical factor will not affect the effective “implementation” (IS) of smart contract in construction supply chain.
- Hypothesis 4 (H4)- “Planning and Compliance Related” (PCR) critical factor will not affect the effective “implementation” (IS) of smart contract in construction supply chain.
- Hypothesis 5 (H5)- “Unethical Practice Related” (UPR) critical factor will not affect the effective “implementation” (IS) of smart contract in construction SCM.
- Hypothesis 6 (H6)- Smart contract “implementation” (IS) does not effect on “Environmental Bottom-line” (ENB) performance of construction SCM.
- Hypothesis 7 (H7)- Smart contract “implementation” (IS) does not effect on “Social Bottom-line” (SOB) performance of construction SCM.
- Hypothesis 8 (H8)- Smart contract “implementation” (IS) does not effect on “Economic Bottom-line” (ECB) performance in construction supply chain.

  The model is aimed to test the effect of ‘CSFs’ and ‘Level and extent of BLT usage’ on ‘implementation success’ along with the effect of ‘implementation success’ on ‘firm performance’. Identified 326 supply chain professionals in construction and chemical industries validated their profiles. 190 out of 326 agreed to participate in the survey and finally 115 respondents provided the response through questionnaire. These 115 respondents belonged to a good mix of different age groups, industry sectors, departments, geographical regions, designations. The collected data had been tested for reliability, multivariate analysis, exploratory factor analysis. The five factors accounted for 80.4 percent of variation in 28 variables against the acceptable range of 50 percent. Factor analysis done for success indicators with 17 variables load on to 3 factors, where Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy came at a statistically significant values of 0.899 against the acceptable range of 0.07. Post exploratory factor analysis, 28 variables have been divided into 5 factors and 17 variables into 3 factors. Model fit of the measurement model was carried out with estimations and correlations, with all values being statistically significant at 99 percent confidence level. Confirmatory factor analysis (CFA) represented by measurement models are prepared using

AMOS 23.0. This research has considered the importance of sector specific CSF in implementation of Blockchain based Supply Chain among Indian Construction companies. It highlights the importance of Smart Contract to drive “Environmental Bottom-Line (ENV)”, “Social Bottom-Line (SOB)” and “Economic Bottom-Line (ECB)” of business encountering Challenges in Construction Supply Chain Management.

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CHAPTER 1

INTRODUCTION

In today's perfect competition and price war market scenario in the Indian construction industry, no organisation can sustain continued growth just by adopting any or all of the following strategies:

- Price increase
- Value Engineering
- Product Superiority
- Reverse engineering
- Recourse Optimization etc.

The competitive edge must be reimagined and recreated in different ways on a continuous basis. Cost savings through minimizing or eliminating wastes can add huge value to the bottom line of business.

Supply chain is one of the activities which has got unlimited opportunity to minimize waste through innovative approaches and save cost of the product or services. In India, the Supply Chain is effective but not efficient to the extent required. In the present COVID-19 situation, the cost of trust is becoming an acute deterrent to the Supply Chain efficiency.

Transparency, trustworthy ecosystem, robust business process and discipline can make it more effective but considering the need of the day, adaptation of digitalization can make it more efficient by unlock value. Reduction in supply chain cycle time not only makes the organization profitable but also increases the sustainability of business.

"With increasing complex construction projects along with increasing quality demands the industry looks towards ways to reassure the sustainability of the materials throughout the supply-chain" (Pryke, 2009). "The way to achieve these parameters could be supported by digital tools. The focus of these tools would mainly need to improve the traceability and transparency in order to verify the quality of the materials" (Čuš-Babič et al, 2014).

In the construction industry, most of the organizations suffer losses because of the ineffective and inefficient supply chain management.

Construction Industry by description is less disciplined and organized worldwide compared to

manufacturing and process industries, where productivity increase is less than 1percent year on year over last two decades and Time & Cost overrun is a norm.

The scenario in Indian Construction Industry is no different, rather more fragmented in nature. According to the latest report for August 2022 of Ministry of Statistics and Programme Implementation, Government of India (Statista Research Department, 2022), which monitors construction projects of Rs 150 crore and above, out of 1526 projects, 393 reported cost overruns and as many as 647 projects were delayed. According to the report, the expenditure incurred on these projects till August 2022 was Rs 13,60,645.94 crore, or 52.49 percent of the anticipated cost of the projects. Total original cost of implementation of the 1526 projects was Rs 21,26,460.93 crore and their anticipated completion cost is likely to be Rs 25,91,823.45 crore, which reflects overall cost overruns of Rs 4,65,362.52 crore.

Even top players of the Indian Construction Industry are lagging in developing a matured SCM because of the following reasons.

- Data is still people-dependent
- There is widespread non-compliance to standard operating procedures (SOP)
- Lack of consolidated procurement plans
- Extremely low awareness of sustainability
- Lethargic exercise of inventory management
- Sloppy collaborations & trust even among the internal stakeholders
- Lack of Global strategic mindset
- Big basket picture is missing

In the present context of post-COVID 19, the entire world is facing the challenge of managing supply chain effectively and efficiently, causing a huge threat to human lives. The supply chain is strongly challenged by the business because of the high dependency of sources in a concentric geographical area.

All the global consultants like McKinsey, Boston Consulting Group (BCG), KPMG, E &Y, Accenture etc are relentlessly searching the way forward to guide the global industries to avoid disruption in SCM.

The construction industry in India is anticipated to face a massive set back post COVID 19 situations, because most of the contracts are not **'Smart Contracts'**. Many terms of the

contracts can be interpreted differently by the clients & contractors in their favour, causing many numbers of litigations and finally slowdown and delayed re-start. Even, traceability of different types of sources would be extremely difficult in case of any supply/quality mismatch. Question is who is going to bear the losses over loses.

During the lockdown period, the entire industry understood the necessity of **Smart Contract, as it connects B2B, eliminates the arbitrators & mediators, minimizes human intervention and increases SCM efficiency by improving cycle time and payment flow.**

Success lies in the selection of digitalization tools, effective rolling out of SOP and implementation of the same across the organization, continuous efficiency measurement and prompt addressal of the modification needs.

"A relatively new technology that might meet these criteria is the blockchain technology", (Loop, 2018).

1.1 Supply Chain Management (SCM)

To my understanding, Supply Chain Management is the effective and meaningful linkage of all the stakeholders starting from point of origin to point of final consumption of a product or services. The word chain probably indicates a strong bonding among multiple stakeholders (links) yet flexible in every actions and directions for shared benefits. There is a very high amount of dependency by every stakeholder on the other 'Supply chain management starts with the planning and then management of all relevant activities involved in sourcing and procurement, transformation, and logistics management activities involved. Significantly, it also consists of harmonisation and collaboration with channel partners. Those can be suppliers, intermediaries, third party service providers (TPA) and consumers. Fundamentally, supply chain management integrates supply and demand management within and across the stakeholders' (Definition of SCM as per Council of Supply Chain Management Professionals (CSCMP),2017).

"Supply chain management (SCM) is the process of planning, implementing, and controlling the operations of the supply chain with the purpose to satisfy customer requirements as efficiently as possible (Definitions **Oliver and Webber,1982).**

In today's competitive environment SCM is the way of running a business and consists of doing activities which are required to fulfill customers' needs. The competition is no longer between the organizations; it's between the supply chains. Thus, it is essential for an organization to implement supply chain strategy effectively. The top reasons for effective implementation of supply chain are reduced costs of operation, improved inventory, improved customer satisfaction, improved lead times, and increased flexibility. In order to have a successful SCM implementation, the following factors need to be considered:

- Supply chain stakeholders must collaborate with each other to minimise waste and unlock value in the supply chain, thereby creating an environment of trust and transparency.
- Supply chain stakeholders must join hands for creating a long-term relationship and a Sustainable Supply Chain Ecosystem of combined resources (assets, knowledge, capabilities, tools and technologies)
- Integration of supply chain planning following business planning
- Integration of processes between supply chain partners in all functional areas, including sourcing, manufacturing, and distribution
- Future readiness- includes provision of human and financial resources, adequate cutting-edge Digital Technology (Blockchain, Artificial Intelligence, Machine Learning, Robotic Process Automation etc.) systems to facilitate and establish internal SCM objectives that are crucial to enhancing SCM adoption

Therefore, to capitalize supply chain potentiality into reality, organizations need to invest in enabling infrastructure and adoption of Digital Technology. Digital Supply Chain has already gathered prominence in the industry and adoption of digital technologies like Blockchain is going to be a game changing proposition to any organizations in the sustainability driven world.

1.2 Construction Industry Overview

Construction is the biggest industry in the world, and yet, even outside of crises, it is not performing well. The ecosystem represents 13 percent of global GDP, but construction has seen a meagre productivity growth of 1 percent annually for the past two decades. Time and cost overrun is the norm and overall earnings before interests and taxes (EBIT) are only around 5 percent despite the presence of significant risk in the industry. A combination of sustainability requirements, cost pressure, skills scarcity, new materials, industrial approaches, digitalization,

and a new breed of player looks set to transform the value chain. McKinsey Global Institute (MGI) heighted that the construction industry needs to evolve and show ways in which it can change to improve productivity by 50-60 percent and deliver US$ 1.6 trillion a year in incremental global value.

-McKinsey & Company Report (2020).

In India, construction industry registered a growth of 8.1 percent of national GDP in FY 2021-2022. The sector is expected a steady growth at the rate of 6.2 percent during 2023-2026. As per industry forecast, Indian construction industry would reach US$ 1.4 Trillion by 2025 and would contribute to 13 percent of GDP by 2030. (Source https://www.indianmirror.com/indian-industries/2022/construction-2022.html).

India ranked 70 out of 140 countries on global infrastructure quality competitive index.

Source: taskforce report of National Infrastructure Pipeline 2019-2025 released by Nirmala Sitharaman, December 2019.

Opportunities are limitless and adequate resources are available, but without the right knowledge and skillset, all these will end up as numbers only. Transfer of knowledge and development of skillset will improve employability in Indian construction sector, but also ensure construction quality and enhance sustainable construction ecosystem. India is predominantly a leading exporter of construction services in Middle East and Africa. With the enhanced knowledge and skillset improvement, India would be in position to earn much more foreign currency with respect.

Adoption of digital technology can drastically improve the productivity of construction workforce in many ways ensuring trust and transparency in very effective and efficient way. Success lies in the selection of digitalization tools/methods and implementation of the same across the organization, continuous measurement of the efficiency and prompt addressal of the modification needs.

In Indian construction industry, the focus needs to shift from conventional ways of construction supply chain management to Digital Technology enabled supply chain to avoid time & cost overrun, efficiency improvement of each and every activity irrespective of its weightage which in turn will lead to creation of a sustainable supply chain ecosystem. The construction companies recognized the importance of an effective and efficient supply chain. Innovation is rapidly becoming a part and parcel of the construction industry. The industry needs to focus on the following areas to remain competitive and sustainable.

- Ability to collaborate successfully with supply chain partners for mutual benefits
- Ability to predict uncertainty
- Ability to adopt digital technology and strategize future readiness.
- 100percent availability of right product of right quality & right quantity from the right source at the right place at right time and right price (7R).
- Need validation of requirement
- Consolidation of requirements and optimisation of costs
- Ability to analyze and effectively use large data captured
- Digital technology enabled supply chain along with its effective and efficient usage addressing triple bottom-line of business.

1.3 Overview of Indian Economy and Way Forward

India is already the fifth economy in the world and predicted to be a US$5 trillion economy by 2025 with a global ranking of forth. It is predicted that by 2030 India will be at third place among world economies, with nominal Gross Domestic Product (GDP) estimated to be around US$7 Trillion (from the current approximately US$3 trillion)

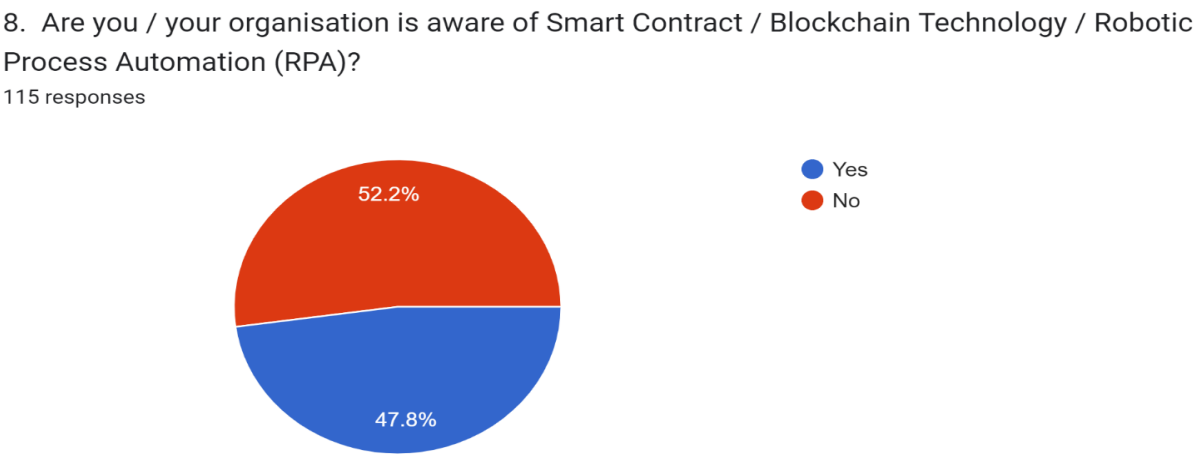
(**FORTUNEINDIA.COM**, **Sep 7, 2022**). In order to remain competitive Indian organizations, need operational and service excellence along with the need to operate supply chain efficiently. Indian organizations need to evolve a supply chain mindset in the organization and need to align supply chain strategy with business strategy to deliver higher customer satisfaction and operational excellence. But poor infrastructure, dispersed markets, lack of updated digital technology and undeveloped suppliers has made supply chain more challenging in Indian context.

The focus of Indian organizations is on effective and efficient supply chain. Digital technology is a key enabler and can help achieve breakthrough in the area of supply chain design, configuration and planning. Thus, Indian organizations need to invest in digital technology-enabled Supply Chain.

1.4 Blockchain-enabled Supply Chain

Blockchain Technology is believed to be the most cost-efficient tool in order to help organizations in the era of globalization and liberalization, gain bigger markets and attract more customers with trust and transparency. Supply Chain is undergoing transformation by adopting Blockchain Technology and organizations are benefited by the adoption of Blockchain Technology - enabled Supply Chain. Blockchain enabled Supply Chain has become an enabler for the organization instead of a defence of competition. Blockchain is at a very nascent stage of application in Supply Chain and at a conceptual stage in construction supply chain, but the silver lying is about 48 percent respondents during my survey confirmed their awareness about Blockchain at organization level. Once adopted, this will revolutionize Construction Supply Chain Management ensuring improved

performance, reducing cost, improving competitiveness, increasing collaboration, flexibility, trust, transparency and traceability of each transaction.



"A relatively new technology that might meet these criteria is the blockchain technology" (Loop, 2018).

Some of the key features of Blockchain-enabled supply chain are:

- Helps in implementation of supply chain strategy and ensures quicker & better decision making
- Provides tangible business value when they are well targeted, well timed, well managed and enabled with complementary investments and actions
- Ensures information availability at a single point of data access, creating visibility to upstream and downstream changes in demand or supply, and enabling effective decision- making
- Delivers information support to decision makers at the time needed and in the format needed
- Links the point of production seamlessly with the point of delivery or purchase
- Helps in quickly adjusting inventory levels, increasing the speed in reacting to customer service problems, reducing the level of paperwork, tracking shipments, improving production scheduling and reducing operational redundancy
- Helps in developing and implementing a variety of flexible supply chain

design options that can create significant cost and value advantages

There is a serious concern with regards to the adoption and success of Blockchain implementations, along with its impact on firm performance. Implementation of Blockchain enabled supply chain requires a committed organization, sustainable change management along with top management support. Alignment of Blockchain objectives with business objectives and proper Blockchain investment justification are also important. Supply chain partners also play a role in implementation of Blockchain enabled supply chain. Trust, cultural alignment, and commitment between supply chain partners, along with investment ability and degree of resource sharing between partners, also play an important role. Training of employees along with thorough understanding of implementation rationale, competence and assurance of job security helps in implementation. It is also important to have Business Process Reengineering (BPR) preparedness along with effective program management, risk-mitigation strategy and governance during implementation. Implementation also depends on choosing the right technology and product along with information security framework. Last but not the least, gaining competitive advantage, peer pressure, involvement of marketing team and focus on consumer affects implementation.

1.5 Need for the Research

In the present complex and aggressive corporate world, supplychain of any organization works under tremendous pressure warranting availability of 7R (right product, right quality, right quantity, right source, right place, right time & right price). The key challenges in SCM are trust, transparency, traceability & data security. Supply chain management is accountable for movement of materials and or services from the place of origin to the place of consumption, meaningfully connecting all the stakeholders in the complete journey. A finished goods reaches to consumers through many mediators (Tier) like whole sellers(C1), Stuckists(C12), agents(C122),

retailors(C1222) etc. whereas the different raw materials required in the process come from numerous tiers of suppliers like S2-S22-S222-S2222….and so on. In case of a defect in the finished goods experienced by a consumer, the traceability of the origin of the defect becomes extremely difficult to the manufacturer or seller generating huge amount of customers dissatisfaction. Blockchain enabled supply chain can provide easy solution to this intricate problem because blockchain locks complete data/details in a block at every transaction ensuring data security, transparency, and traceability. In layman's dialect, Blockchain is a decentralized, tamperproof & secured data management system, which is shared across a network of peers (computers) and each computer is termed as a node.

A lot of research has been done in identifying CSFs impacting Blockchain implementation, success indicators and firm performance measures. From the literature reviewed, it is evident that there is scarcity of research done in Blockchain enabled supply chain and focus has not been Indian construction sector. Thisresearch addresses the gap identified from literature review.

1.6 Problem Statement & Scope of the Study

In order to remain competitive, Indian construction companies need to predict confidently, collaborate successfully with supply chain partners, optimise costs, and prevent stockouts. This requires them to focus on supply chain by leveraging Blockchain Technology to the fullest. Implementing Blockchain Technology in an organization requires both time and money. Every new technology implementation in any organization or industry sector faces different challenges. If we take the example of Information Technology (IT) implementation in Supply Chain Management, it was not at all easy (Chakravorty, S.S. et al., 2016; Yogesh, K.D. et al., 2015; Sar, A. et al., 2012). Along with this, it is essential to measure the level of success for Blockchain Technology enabled Supply Chain along with the benefits realized by the organization and its business partners. Thus, there is a need to measure the impact of Blockchain Technology enabled Supply Chain on firm

performance. This has motivated the researcher to identify critical success factors (CSFs) impacting implementation of Blockchain Technology in construction Supply Chain in India along with its effect on firm performance.

The research is restricted to Indian Construction industry and includes practitioners working in various domains construction industry along with academicians dealing with supply chain, sustainability, Information Technology & Blockchain Technology. As the existing literature is scarce in Blockchain Technology enabled Supply Chain in Indian construction sector, factors identified from Information Technology implementation, other geographies andother industries have been considered for the research purpose. The research has focused on detailed literature review in identification of "CSFs", "Critical Success Indicators" and "Performance Indicators" for implementation of Blockchain Technology around the world and Supply Chain in Indian industry sectors.

This research fills the gap in existing literature by focusing on Indian construction sector as the previous research work in this field lacked focus on Indian construction sector. It also provides guidance to practitioners working in construction sector by focusing on CSFs influencing Blockchain implementation and improved decision making. The research also highlights the importance of 'Construction Sector Specific CSFs which have not been considered in earlier research.

1.7 Conclusion

This research has highlighted the significance of Blockchain Technology to increase efficiency and effectiveness of supply chain in Indian construction industry where time and cost overrun is a norm. In the era of sustainability, where construction industry is a major contributor to the non-compliances, this research focuses on how the implementation of smart contract in construction supply chain affects the triple bottom line of business. It also emphasizes that a sizeable amount of time, cost and involvement are required in Blockchain Technology enabled supply chain specially in construction sector which needs a mindset of achievement. Thus, it is essential for an organization to focus on making

Blockchain Technology enablement of supply chain successful and helps in understanding the problem statement. It gives an overview of Supply Chain, Construction industry, Indian context and the problem statement along with the scope of present research. The next chapter discusses in detail the literature review.

Chapter 2

LITERATURE REVIEW

This chapter focuses on the literature reviews on Blockchain Technology and it's applications in Supply Chain Management in India and around the world, the existing literature on Indian economy, construction industry and its challenges. It highlights the need of supply chain and the role playable by Blockchain Technology. It further details the blockchain technology implemented in other industry sectors and how successful past implementations have been. Finally, it studies the constructs which practitioners should focus on for making Blockchain Technology enabled Supply Chain successful along with 'Critical Success Factors' and 'Performance Indicators'. Period considered for Literature Review is 1992 to 2022 through renowned databases like Scopus, ScienceDirect, JSTOR, Google Scholar, Sodhganga, Web of Science, ABDC. Key words used for the Literature Review are Supply Chain Management, Construction Industry, Blockchain, Infrastructure, Sustainability, Challenges in SCM, COVID, Smart Contract, Procurement, Logistics.

2.1 Introduction

Indian economy was liberalized in 1991 after witnessing a decelerated industrial production, double digit rate of inflation, low level of foreign exchange reserves and a very high ratio of borrowing to Gross National Product (Budhwar, P., 2001). The situation was so pathetic that Government of India was forced to mortgage gold reserve to International Monetary Fund (IMF). 1991 economic reforms initiation resulted in relatively strong performance of Indian economy (Bhatnagar, J. et al., 2010) along with the increased pressure of competing globally. India with a consumer base of over 1.3 billion and despite making steady improvement since 2006 ranks- 28th on GCI (Global Competitiveness Index) score published in 2022. In logistics performance index (LPI) published by World Bank India jumped from 54 (2014) to 35 (2016), six-components of the LPI i.e. Customs, Infrastructure, International Shipments, Logistics Quality and Competence, Tracking and Tracing, and Timeliness, India's ranking is 38, 36, 39, 32, 33 and 42 respectively.

As supply chain is a high impact area in any economy, it always works under pressure. The Global Supply Chain Pressure Index (GSCPI) is a new measurement created by the Federal Reserve Bank of New York. The index evaluates the global supply chain using transportation and manufacturing data. The data shows that supply chain pressure skyrocketed during the pandemic but is starting to ease. GSCPI reached 1.47 points in August 2022, down from 1.75 points in the previous month. (Published by Statista Research Department, Sep 28, 2022).

India leads in digital skills readiness for future of work. Among 19 countries, India has the Index's highest digital readiness score at 63 out of 100 (average global readiness score was 33 out of 100).04-Feb-2022

India will contribute 10percent of the world trade, and taking the country's share of exports in GDP to about 25 per cent (Business Standard et al., 2022). India needs to put in a lot of effort to achieve this and based on the previous research some of the obstructions that need special attention are:

- Supply chain partnership mindset is missing (Sahay, B.S. et al., 2003)
- 1/3rd of the organizations don’t have a supply chain strategy in place (Sahay, B.S. et al.,2003)
- Culture is more authoritative instead of participative and the management doesn’t make information transparent to everyone (Annamalai, C. et al., 2013)
- Poor state of logistics infrastructure- Raw Material Inventory of 33.41 days, Works in Progress of 14.25 days and Finished Goods of 16.09 days (Sahay, B.S. et al., 2001)
- Psychological and leadership-related impediments affect the change efforts (Ramnarayan, S., 2003)

At the end, need is to deploy IT-enabled Supply Chain to foster collaboration, flexibility, speed and accuracy.

The previous research highlights that though there is an increase in Internet Penetration (Rise from 11percent of the population (current penetration, global average is 36percent) to 50percent of the population by 2025), Mobile Penetration (increase from current level of 73percent to 100percent by 2025) and Social Media Adoption (Increase in number of users from current 90 million to 500-600 million by 2025) (Madhavan, K. et al., 2014). IT spending for Indian organizations is 1.3percent as compared with the overall global average of 4.93percent worldwide (Sahay, B.S. et al., 2003). Also, Indian organizations are reluctant to adopt new technologies as IT is still a luxury with organizations (Borade, B.A. et al., 2010; Sharma, M.K. et al., 2005).

Thus focus of Indian organizations should be on effective and efficient implementation of IT-enabled Supply Chain.

2.2 Construction Industry

India is expected to become the third-largest construction market globally by 2022. India plans to spend US$ 1.4 trillion on infrastructure projects through the National Infrastructure Pipeline (NIP), from 2019 to 2023, to ensure sustainable development in the country. India stood 10th worldwide with respect to overall quality infrastructure environment in the country. (Infrastructure Industry Report, June 2022).

GDP from Construction in India decreased to 2629.18 INR Billion (US$33 Billion approx.) in the second quarter of 2022 from 3382.83 INR Billion (US$ 42 Billion approx.) in the first quarter of 2022.

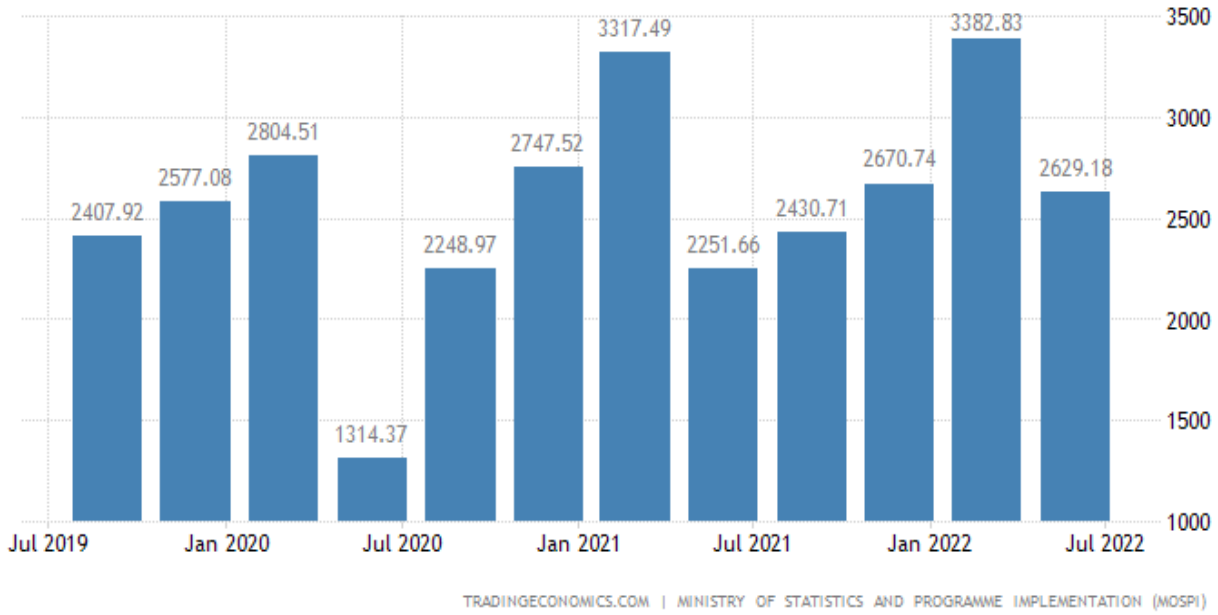


Figure 2.1: GDP of Construction Industry

Construction companies have traditionally been dependent on small and medium scale enterprises (SMEs) (Thakkar, J. et al., 2008). 90 percent of suppliers and contractors in the construction industry in India are MSME. The industry suffers losses in time and cost overruns,

mainly owing to a lack of trust, transparency, and traceability in the absence of digital technology-based supply chain management.

India having the highest Index's in digital readiness score of 63 out of 100 (average global readiness score was 33 out of 100) and available 5G technology (inaugurated by Prime Minster Narendra Modi on 1st October 2022, India stands a very high opportunity to drive construction supply chain with the support of digital technology like Blockchain to strengthen the areas of **trust, transparency and traceability and** develop a sustainable supply chain ecosystem.

Government of India has formed a Technology Innovation Group for the design and development of 6G technology by 2030 (Business Standard, September 27, 2022) which would take Indian construction supply chain to a new height.

Some characteristics of construction companies are as follows:

- Purchased by consumers with minimum effort on everyday basis (Dibb, S. et al.,2006; Corney, D., 2002; Kotler, P., 2000)
- Major investment is made to build brands and leverage brand as a competitive tool (Mann, B.J.S. et al., 2012)
- Characterized by intense competition (Sahay, B.S., 2003)
- Highly competitive market and thus difficult to develop brand loyalty (Steele, W. et al.,1994)
- Statistically significantly higher returns for shareholders (Mann, B.J.S. et al., 2012)
- Lack of focus on the requirements of the end consumer at the supply chain level (Zokaei,K. et al., 2007)
- Increasingly challenging in terms of innovation with a failure rate of 80percent (Kotler, P., 2000)

2.2.1 Construction Classification

Construction companies can be classified based on the type of construction projects and business activities, as shown in Figure 2.1.

The classifications of construction projects and business activities of the largest construction company of India Larsen & Toubro Construction) are mentioned below.

a. Building & factories

b. Heavy civil infrastructures
c. Geo-structures
d. Smart world
e. Power transmission and distribution
f. Minerals and metals
g. Railways
h. Transportation infrastructures
i. Water & effluent systems

2.2.2 Challenges in Construction Industry

Although 100 percent availability of the right product of the right quality and quantity from the right source at the right place at the right time at the right price is the philosophy of the supply chain, construction companies need to compete on all dimensions of competitive priorities such as fastest delivery, high quality, lowest price, volume, and product flexibility in order to increase the market share. Some of the challenges faced by Construction companies are as follows:

- Ability to forecast consumer demand accurately (Adebanjo, D. et al., 2000). Volatility, variability and unpredictability in consumer demand by frequent sales promotions and ineffective management of promotion (poor planning, lack of timely data to restructure the promotion and delay in settling the payouts to the channel partners) (Bansal, S. et al., 2016; Noorani, S.H. et al., 2007, Steele, W. et al., 1994). Construction companies use STM to gauge the buyers' reactions to a product, advertising or marketing mix variations so as to forecast new product sales (Korotkov, N. et al., 2013)
- Effective inventory policy in place to ensure zero out-of-stocks (OOS) (Steele, W. et al., 1994). There is a clear loss of 35 percent due to OOS for a construction company, along with a 15

percent delay in purchase. (which might result in future loss) (Corsten, D. et al., 2003). By addressing OOS issue, earnings per share of upto 5percent can be boosted. Average OOS is reported to 8.3percent and the average sales loss due to OOS is 3.9percent (Corsten, D. et al., 2003).

- Ability to launch new products due to incorrect research, incorrect pricing and improper promotional support are some of the primary concerns (Noorani, S.H. et al., 2007). 89percent of all new products are line extensions, 6 percent are brand extensions and only 5percent involves a new brand name (Aaker, D.A., 1991)
- Ability to understand what happens at the "first moment of truth" (FMOT) correctly in store (Inman, J. et al., 2009). Relationship marketing is largely impersonal in nature, non-differentiating and doesn't work towards the development of relationships. Consumers' also felt an absence of commitment, trust, interpersonal interactions and positive attitudesin their interactions with Construction companies (Rose, L., 2009)
- Ability to understand the Construction ecosystem (consumers, competition and convergence) successfully and accordingly acting on it (Sahay, B.S et al., 2003).
- Ability to understand the relationship between profit maximization and retention incentives by improving churn management practices (Tamaddoni, A., et al., 2017)
- Ability to make brand acquisition successful. Construction companies pursue most of the brand acquisitions and Indian companies acquire brands within India as well as in foreign land (Mann, B.J.S. et al., 2012)
- Construction companies face difficulty in making promotional decisions leading to an uncertain end result of promotional activity and yet promotional activities receive a considerable percentage of budgets (Tang, C.Y. et al., 2014)

2.3 Supply Chain Management (SCM)

SCM as defined by various researchers

Supply chain encompasses all activities associated with the flow and transformation of goods from the raw material stage (extraction), through to the end user as well as all information flows. (Hanfield, B.R. et al., 1999)

Practice of co-coordinating the flow of goods, services, information, and finances as theymove from raw material to parts supplier to manufacturer to wholesaler to retailer to consumer. (Russell, K., 2001)

Supply Chain Management is the systemic, strategic coordination of the traditionalbusiness functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole (Mentzer, J.T. et al., 2001)

Supply Chain Management is the integration of social, economic and environmental aspects that provide sustainable product, excellent services and accurate information sharing (Kuik, S.S. et al., 2011)

Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channelpartners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. (Council of Supply Chain Management Professionals (CSCMP), 2017)

The SCM framework consists of three closely interrelated elements (Lambert, M.D., et al., 2000)

- Supply Chain Network: consists of member firms and the links between them
- Business Processes: activities that produce a specific output of value
- Management Components: Managerial variables by which Business Processes are integrated and managed

Supply chains are dynamic in nature and require constant revision and fine-tuning to make sure that any undesired performance is identified, analyzed and improved. (Barros, A.C. et al., 2013). SCM has evolved over years from traditional manufacturing/ distribution model to integrated JIT(Just-in-Time) to lean manufacturing, cellular operations, mass customization to agile SCM. In order to successfully compete in today's market SCM plays an important role (Ashby, A. et al.,2012) and focus on SCM has increased because:

- Organizations are spending as much as three-quarters of their revenue on supply chain activities (Ellinger, A.E. et al., 2014)
- Performance of an organization is enhanced by supply chain responsiveness (Qrunfleh, S.et al., 2013)
- Emergence of new types of Inter-Organizational relationships (Thakkar, J. et al., 2012; Handfield, R.B. et al., 1999)
- Volatility has increased in the business environment (Christopher, M. et al., 2011)
- Increased external pressures in the form of technology advancement, maintaining lower cost and intensified competition (Fawcett, E.S. et al., 2008)
- Attain competitive advantage by reducing cost, improving flexibility, enhancing quality, increasing market share, improving time to market and ensuring customer satisfaction (Zelbst, J.P. et al., 2010; Dos, S.B.L. et al., 2008; Chandra, C. et al., 2000; Shin, H. et al., 2000;

Handfield, B.R. et al., 1999)

- Minimize monetary risks and increase profits (Fawcett, S.E. et al., 2008)
- Deliver superior customer value at less cost (Christopher, M., 1998)
- Reduce waste by ensuring all resources are creating value (Barros, A.C. et al., 2013)

2.3.1 Construction Supply Chain

There is a growing importance of SCM for Indian Construction companies (Sahay, B.S. et al., 2002). Supply chain collaboration practices in Construction industry has evolved over years from VMI (Vendor Managed Inventory) to CPR (continuous replenishment program) to category management to CPFR (collaborative planning, forecasting and replenishment) to RFID-enabled collaboration. VMI and CRP addresses the supply side (efficient replenishment and supply), whereas Category Management and CPFR gives more emphasis on the demand side. (Pramatari, K., 2007).

As per the previous research, the four stages of supply chain evolution for Construction industry are (Lowson, H. R., 2001).

- Stage 1- participants (raw material supplies, operational processes- manufacturing, logistics, etc., customer serving processes) are separate entities with no interconnection with each other
- Stage 2- recognizes the importance of inter-dependence with some attempt of cooperation
- Stage 3- EDI (Electronic Data Interchange) formed an interface between various participants responding to a consumer pull
- Stage 4- termed as cluster of value. Consumer group is the nucleus of activity driving and dictating all demand preferences. All entities (customer serving process, operations process, raw material supplier) respond by providing value in the form required. Companies employ multiple operational strategies tailored to address individual needs and circumstances

Construction supply chain consists of three interlinked components (Battezzati, L. et al., 2000)

- Operations- consists of suppliers and 3rd parties involved in purchase, production and distribution
- Design functions- consists of R&D and marketing functions, focusing on adjustment of demand to the variability of market demands
- Market component- distributes the products to end consumers via various channels

A typical supply chain flow diagram followed by major construction supply chain is depicted in figure 2.2

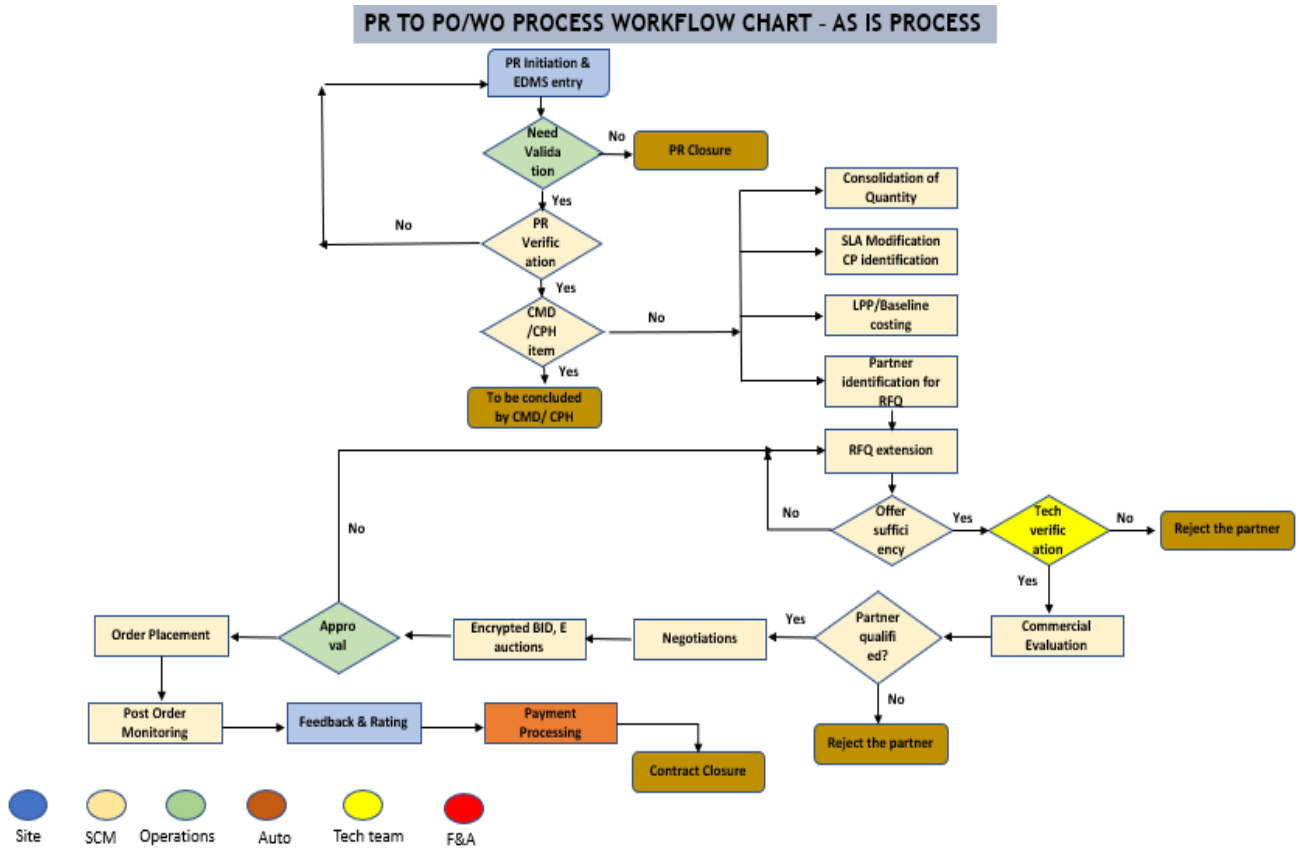


Figure 2.2: Construction Supply Chain Workflow-As is in L&T

2.3.2 Supply Chain Strategy

Globalization and recent economic trends have created highly complex & adaptive supply chains(Tummala, R. et al., 2011; Wycisk, C. et al., 2008). The key characteristics of a highly complex supply chain are- vastness of data, decision variables, intricate interrelationships among variablesand system constraints, and performance trade-offs (Manuj, I. et al., 2011). The efficient and effective management of supply chain poses many challenges (Ellinger, A.E. et al., 2002). Efficient and effective execution of SCM results in improving organizations performance (Kotzab, H. et al., 2011).

In order to implement an effective "supply chain strategy" it becomes imperative to develop common mission, goals, and objectives for the group as a whole, while pursuing independent policies at individual members' level. (Chandra, C. et al., 2000). Strategic supply chains are where the "members are strategically, operationally, and technologically integrated" and are anticipated for long-term stable relationships with the ability to change demands of the environment (Hult, G. et al., 2004).

Supply chain strategy should be aligned to the overall business strategy. Based on previous research, key pillars of excellence in an effective supply chain strategy is depicted below.

Table 2.1: Key Pillars of Excellence

S.No	Pillars of effective Supply Chain Strategy	Author & Year
1	Inter-temporal integration of supply chain activities over strategic, tactical and operational planning horizon	Sehgal, S. et al., 2006
2	Moving towards borderless supply chain culture or seamless supply chain	Fawcett, S.E. et al., 2006; Jones, R.M. et al., 1997

3	End-to-end focus on integration of business processes throughout the value chain	Evelyne, V. et al., 2017; Green, K.Jr. et al., 2008; Serve, M. et al., 2002
4	Flexible supply chain- providing customers with customized products	Qi, Y. et al., 2011
5	Internal collaboration- clear vision of how each function within the organization can work together	Stank, P.T. et al., 2011
6	External collaboration- collaborating externally with both suppliers and customers	Stank, P.T. et al., 2011; Faisal, M. N. et al., 2007
7	Technology- right supply chain technology is chosen and implemented	Stank, P.T. et al., 2011
8	Waste elimination and sharing information within the supply chain	Li, S. et al., 2006
9	Managing change- careful attention needs to be given to project and change management	Stank, P.T. et al., 2011
10	Talent- ensuring that the right talent is in place to execute a strategy	Stank, P.T. et al., 2011

Supply chain strategy implementation requires investment in Blockchain Technology that supports coordination and flexibility among supply chain entities, creation of formal and informal modes of communication, standardization of information and processes, centralized planning decision- making supporting decentralized implementation of plans, and integrated individual and organizational reward structures that target overall supply chain goals." (Defee, C.C., 2005). IT acts as a critical enabler of supply chain (Auramo, J. et al., 2005) with a goal to make decisions more quickly and with 100 percent accuracy (Tummala, R. et al., 2006).

2.4 Blockchain Technology -enabled Supply Chain

Basic characteristics of a Digital Technology Blockchain -enabled SCM system are (Corney, D., 2002)

- Flexibility
- Speed
- Ability to learn
- Adaptability
- Ability to deal with complexity
- Explanatory power
- Trust
- Transparency
- Traceability

Competitive advantage, supply chain efficiency and effectiveness have increased focus on Blockchain Technology- enabled Supply Chain (Premkumar, G.P., 2000). Previous researches also indicate growing interest in IT-enabled Supply Chain and the same is described below.

Table 2.2: Growing interest in Blockchain enabled Supply Chain

Detail of journals/ Books/ website links	**Publication Year**	**Indexing of journal**	**Major relevant findings or conclusion to projected research work**	**Remarks**
Blockchain-integrated technologies for solving	2022	Scopus	This paper shows how blockchain technology improves flexibility and agility in supply chain	Blockchain is finding the way in industries due to its lean and efficient nature. It is beneficial to

supply chain challenges; Dhruman Gohil, Shivangi Viral Thakker, https://www.emerald.com/insight/content/doi/10			management. The combination of blockchain and other recently developed digital technologies can improve dealing with supply chain uncertainties and disputes being faced by the ecosystem.	use the smart technologies to make supply chain green, sustainable, agile, transparent and high degree of traceability.
Determinants of Blockchain Technology Adoption in Supply Chain by Small and Medium Enterprises (SME) in India; Amit Kumar Bhardwaj, Arunesh Garg, Yuvraj Gajpal	2022	Scopus	In modern times, organizations are progressively implementing blockchain technology in supply chains for cost optimisation and effective data management, transparency and route tracing. This paper analysed the factors affecting the intent of small and medium enterprises (SMEs) in India to adopt blockchain technology	SMEs will be more inclined to adopt blockchain technology if top management has a favorable attitude to the technology

https://doi.org/10.1155/2021/5537395			in their supply chain	
What are the key drivers of Blockchain Implementation within Supply Chain?- An exploratory research; Leonor Jardim, Samuel Pranto, Pedro Ruivo, Tiago Oliveira http://creativecommons.org	2021	Scopus	This paper discusses some concerns regarding the adoption of Blockchain in supply chain. It also discusses the advantages of Blockchain in SCM over the challenges of this digital technology.	Blockchain can integrate many willing investors in a complex SCM. It incentivizes data integrity, transparency and traceability of SCM having smart contract as one of the determinant feature.
Factors influencing Blockchain implementation in	2021	Scopus	This paper mentions the important features of Blockchain like real time information/data sharing among	It emphasizes the role of Blockchain in developing close relationship with business partners, collaboration with

Supply Chain Management services; Javed Aslam, Aqeela Saleem, Nokhaiz Tariq Khan			stakeholders, data security, reliability, transparency, traceability, visibility.	internal & external stakeholders, importance of digitalized strategic sourcing etc.
New organizational shifts with Blockchain-A focus on the supply chain; Vincenzo Varriale, Antonello Cammarano, Francesca Micheleno, Mauro Caputo https://www.emerald.com/insight/0953-4814.htm	2021	Scopus	Blockchain creates collective Peer to Peer and Business to Business digital marketplace. This paper displays across 31 variables categorised into negative, positive, and future direction of digital technology in the supply chain.	One of the goals of supply chain is to ensure availability of supplies or services at the time and place of demand at the lowest cost. Blockchain technology can fulfill that goal even in the most complex supply chain applications.
Blockchain	2021	Scopus	Paper discussed about	Evaluated recent use

enabled Supply Chain: Analysis, challenges and future directions; Sohail Jabbar, Huw Lloyd, Mohammad Hamoudeh, Bamidele Adebisi, Umar Raja; https://link.springer.com/article/10.1007/s00530-020-00687-0			controlling the integrity of products and methods in a multi-participant supply chain ecosystem is a considerable challenge. Technical and non-technical challenges of Blockchain are acutely evaluated, along with several unanimity algorithms for functions in the supply chain.	cases and startups in the field of Blockchain-supported supply chains. Also identified some key areas as future research directions and proposed MOHBS Chain, a novel structure for Blockchain-supported supply chains.
The next normal in construction -How disruption is reshaping the world's largest ecosystem; McKinsey	2020		Construction is the largest industry in the world and still is not performing as expected. The construction ecosystem represents 13 percent of global GDP, yet saw a miserable productivity growth of 1 percent	Highlighted the areas of global concerns in construction industry and advocated for the skillset development and digitalization as a tool to improve productivity and sustainability in the sector.

& Company			year on year for the last two decades. Time and cost overrun is the norm and overall earnings before interests and taxes (EBIT) are only around 5 percent despite the presence of substantial risk in the business	
Blockchain critical success factors for sustainable supply chain; Sachin Yadav, Surya Prakash Singh; Resources Conservation & Recycling; https://doi.org/10.1016/j.resconrec.2019.104505	2020	Impact Factor: 8.806	The conventional supply chain is no longer in a position to meet the expectation of the customers of higher quality at lowest price, which has given birth to the steep price war in the SCM space. The paper speaks about the effectiveness of blockchain technology in sustainable SCM.	In the ongoing COVID situation, where the construction industry is going through an unprecedented challenging situation, the demand for a more effective construction supply chain is skyrocketing.
Boundary	2020	Impact	Food industry in itself	Similarly in the

conditions for traceability in food supply chains using blockchain technology; Kay Behnke, M.F.W.H.A. Janssen; International Journal of Information Management ; https://doi.org/10.1016/j.ijinfomgt.2019.05.025		factor: 8.210	is very sensitive in nature, traceability of sources of components is even more sensitive. The highest challenge of the food stuff supply chain lies in the effectiveness of source traceability. The paper discusses the food stuff supply chain boundary conditions used for standardization of traceability of processed food ingredients and effectiveness of digital technology like blockchain in achieving the level of traceability.	construction SCM, traceability of sources of the components/materials become extremely important in the event of a post failure root cause analysis(RCA). In most of the cases the implementation of RCA results ceases its effectiveness due to the unavailability of source traceability. Blockchain technology can efficiently be adopted and implemented to have a higher impact of traceability.
Modeling the blockchain supported traceability in the agriculture supply chain; Sachin S.	2020	Impact factor: 8.210	As the supply chain deals with multiple stakeholders, trust factor plays an important role in the effectiveness of SCM. This paper describes the influence of blockchain technology in bridging the trust deficits	Construction industry is less disciplined compared to manufacturing and other service industries. Construction supply chain sector is even more fragmented in terms of trust factor. The impact of trust deficit in Indian

Kamble, Angappa Gunasekaran, Rohit Sharma; International Journal of Information Management; https://doi.org/10.1016/j.ijinfomgt.2019.05.023			amongst the participants in Indian context.	construction supply chain is even more prominent in the present COVID '19 impacted economy.
Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs; T Lai-Wan Wong, Lai-	2020	Impact factor: 8.210	The Industry 4.0 model has brought a revolution in the digitalisation drive across the industries. The data captured by the IOT devices installed in the equipment multiplies the effectiveness of the model when the data is blockchain driven. This article describes the adoption of blockchain technology for supply chain management	In Indian construction supply chain, about 70percent stakeholders belong to the MSME category. With support of the government, the MSME segment generates 30percent of the GDP. Considering the contribution to GDP from construction as of the fourth quarter of 2020 is 2.7 trillion INR, the importance of the MSME sector is very high. Even a single digit

Ying Leong *et al*; Journal of Information Management ; https://doi.org/10.1016/j.ijinfomgt.2019.08.005			among the small medium enterprises(SMEs) in Malaysia.	increase in efficiency of MSME SCM, would prove to be game-changing.
Real estate revolution on Blockchain Alley; Richard Bloxam JLL; https://www.jll.cz/cz/trendy-a-postrehy/mesta/real-estate-revolution-blockchain-alley	2020	-	The understanding of Blockchain technology for most people is related to cryptocurrency. This article sheds light on how the construction industry leaders, blockchain industry leaders, are coming together to develop this technology for mutual benefit.	Indian construction Industry is no different in terms of understanding of blockchain technology. However, many organisations understood the benefit of digitalisation in construction SCM. If this digitalisation is backed by blockchain, the effectiveness of the construction SCM can reach new heights.
US Homeland	2020	-	Blockchain brings transparency in the	In the COVID like situation in India where

Security lists blockchain as Covid-19 critical service; Ledger Insights; https://www.ledgerinsights.com/us-homeland-security-lists-blockchain-as-covid-19-critical-service/			distribution system even in difficult times. This article describes how blockchain helped the cybersecurity and infrastructure security agencies in the US Department of Homeland Security during COVID '19 essential commodities distribution.	order cancellation is very common leading to insolvency of many MSMEs. Blockchain based supply chains may appear as a dispute resolution agent saving cost and integrity in the sector.
How Blockchain Will Change Construction; Don Tapscott and Ricardo Viana Vargas; Harvard Business Review;	2019	-	Blockchain is amongst the most disruptive technologies of the previous decade. The power to record, enable, and secure gigantic numbers and varieties of dealings raises an interesting question: Whether the distributed ledger technology that controls bitcoin	Indian supply chain management is effective but not efficient enough. Adoption of blockchain technology in Indian construction supply chain will not only increase the efficiency of SCM but will also ease out dispute resolution, transparency, and sustainable ecosystem.

https://hbr.org/2019/07/how-blockchain-will-change-construction			transactions would be able to enhance better execution of strategic projects in a traditional sector like construction, which involves big teams of contractors and subcontractors and an plenty of building codes, safety guidelines, and standards,.	
Blockchain in Construction: 4 Ways It Could Revolutionize the Industry; Grace Ellis; Digital Builder; https://constructionblog.autodesk.com/blockchain-in-construction/	2019	-	As blockchain system is structured to continuously keep posting of digital records, it is obviously a technology that could transform the way that project teams build in the way forward. Basically, blockchain technology in construction industry has got the potential to be a gamechanger. [**a]Smart Contracts, [b] BIM, [c] Payments, [d] Supply**	The success of smart contracts lie in the bar of manual intervention. In Indian construction supply chain, most of the disputes arise because of lack of accountability by the stakeholders. In the present era, most of the supplies got disrupted because of the lockdown, causing a number of disputes in the contract management. Suppliers are exposed to penalties, and users are exposed to unnecessary inventory

			Chain Management.	holding costs. Simply, this issue can be avoided through smart contracts.
Real-time supply chain—A blockchain architecture for project deliveries; Petri Helo, A.H.M.Sham suzzoha; Robotics and Computer-Integrated Manufacturing; https://doi.org/10.1016/j.rcim.2019.101909	2019	Impact Factor: 5.057	The information flow is required by project managers to maintain real time visibility of the data from the production process to transportation to material management.	In Indian Construction Industry, the weightage given to the supply chain efficiency is as high as 40percent. Most of the projects get delayed due to the inefficient supply chain. A blockchain based real-time supply chain tracking can really increase the efficiency of supply chain and help project completion as per the schedule avoiding cost overrun.
Blockchain technology: could it revolutionise construction ?; Adam	2018	-	The construction industry has been consistently been quoted as one of the most disjointed, high impact sectors and has consistently been	One of the major challenges in the construction supply chain is the timely payment to the suppliers. Though the consortium blockchain model, the payment

Kirkup; Institution of Civil Engineers; https://www.ice.org.uk/news-and-insight/the-civil-engineer/december-2018/can-blockchain-transform-construction#:~:text=Blockchainpercent20canpercent20deliverpercent20apercent20more,andpercent20complexitypercent20ofpercent20majorpercent20projects.&text=Togetherpercent20withpercent20BIMpercent20(Bui			argued to increase its efficiency, productivity, and incorporate the opportunities presented by evolving technologies. Reforming contracts, payments, procurement and asset management with life-cycle costing.	tracking by the stakeholders becomes a very transparent activity and releases stress from the other activities in the supply chain.

ldingpercent 20Informatio n,aspectsperc ent20ofperce nt20apercent 20constructi onpercent20 project.				
How blockchain is helping investors value real estate; Jones Lang Lasalle et al; JLL; https://www.jll.co.in/en/trends-and-insights/investor/how-blockchain-is-helping-investors-value-real-estate	2018	-	Blockchain technology is capable to bring clarity to investors by operating alongside other technologies, like artificial intelligence (AI), machine learning and Robotic Process Automation.	Indian construction supply chain is on its growth path. Adopting blockchain technology at this stage would be more effective and value added compared to matured economies.
The Fundamentals of Blockchain:	2018	-	Blockchain Technology is a thoughtful secret innovation. unquestionably one of	The advantages of blockchain technology mentioned in the previous section also

An Overview; Vandana Mansur; The Internet of Things Community; https://medium.com/iothincvit/fundamentals-of-blockchain-an-overview-5120f26505ea			the most incredible invention after the internet. It is growing so rapidly that people who haven't heard of what it in fact is or know its workflow, are ready to invest and discover this field. **Blockchain stand out: Features.** 1.Enhanced Capacity, 2.Nicer Security, 3. Immutableness 4.Quicker Settlement, 5.Distributed System, 6. Stamping **Blockchain Types** 1.Public Blockchain 2.Private Blockchain 3.Hybrid Blockchain 4.Consortium Blockchain	apply to the Indian construction supply chain, and will substantially optimise the operating cost.

A Blockchain enabled supply chain flow diagram in construction supply chain is indicated in figure 2.3

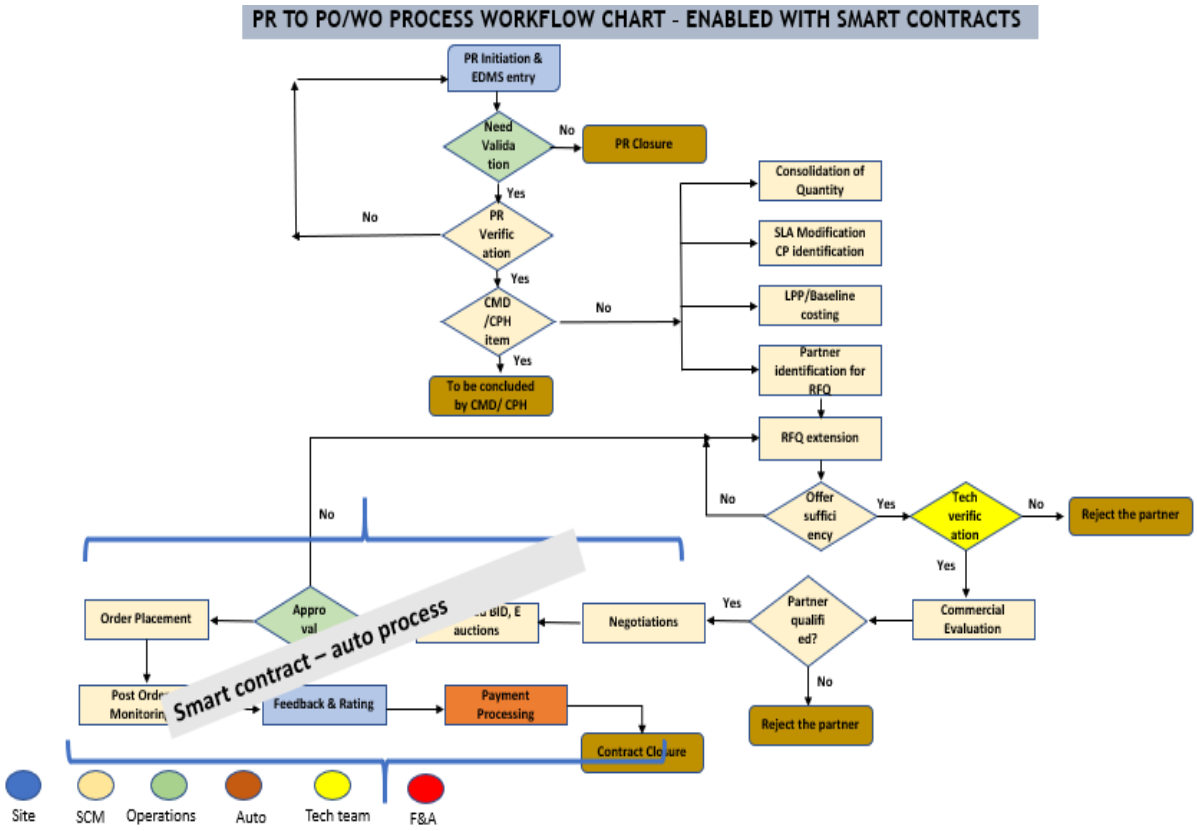


Figure 2.3: Construction Supply Chain workflow-Blockchain enabled-To be.

Previous research have highlighted that while implementing new supply chain technology some important rules need to be followed. The same are highlighted below.

Table 2.3: Rules for Implementing New Supply Chain Technology.

S.No	Rules for implementing new supply chain technology	Author and Year
1	Technology is used appropriately	Stank, P.T. et al., 2011
2	Human-technology interface is handled carefully	Stank, P.T. et al., 2011
3	Technology readiness of an organization need to be measured before choosing a new technology.	Parasuraman, A., 2000

4	Technology implementation is part of a larger businessvision & strategy	Annamalai, C. et al., 2013
5	Presence of a clear business case	Stank, P.T. et al., 2011
6	Accepted communication protocols are followed by all members of the supply chain ecosystem.	Ahuja, V. et al., 2010

Technology delivers the following benefits in Supply Chain.

- Improves supply chain performance (Qrunfleh, S. et al., 2012; Li, G. et al., 2008) and financial performance (Evelyne, V. et al., 2017; Bharadwaj, A.S., 2000) by improving usefulness of decision-authorities (Chen, I.J. et al., 2004).
- Reduces order cycle time (Lin, F. et al., 2002)
- Reduces cost (Zhao, X. et al., 2002; Lymer, A., 1997)
- Improves overall competitiveness (Alberto, B.M. et al., 2007)
- Provides higher levels of product and process innovation (Raymond, L. et al., 2008)
- Increases operational efficiency (Somuyiwa, A., O. et al., 2010) by reducing processinglead time and eliminating errors (Brah, S.A. et al., 2006)
- Reduces high level of supply chain complication (Manuj, I. et al., 2011)
- Inside and outside-organizational collaboration along with monitoring and visibility of the extended supply chain (Thakkar, J. et al., 2008). Increased collaboration among supply chain partners allows them to share workflow, capabilities and information with each other (Vinum, T., 2001; Mason-Jones, R. et al., 1997). Collaboration takes place at 3 levels (Kotzab, H. et al., 2003)
- Business integration- coordinated strategy across supply chain
- Application integration- physical integration of software and hardware
- Technical integration- data integration

- Increases flexibility: focused towards market flexibility and quick strategic decision support

(Sabherwal, R., 2001)

- Achieves supply chain agility by linking functional areas all over the organization (Esper, L.T. et al., 2010)
- Reduces environmental uncertainty by providing real-time accurate information (Narasimhan, R., 2001; Radstaak, B.G., 1998). As per Jack G.A.J.V. et al., 2002 "uncertainty refers to decision making situation in the supply chain in which the decision maker does not definitely know what to decide as he is indistinct about the objectives, lacks information about or understanding of the supply chain or its environment; lacks information processing capacities; is unable to accurately predict the impact of possible control actions on supply chain behavior; or, lacks effective control actions (non- controllability)"
- Improves cooperation and coordination in horizontal and vertical directions in supply chain (Kumar, K., 2001)

2.4.1 Blockchain Technology Applications in Supply chain

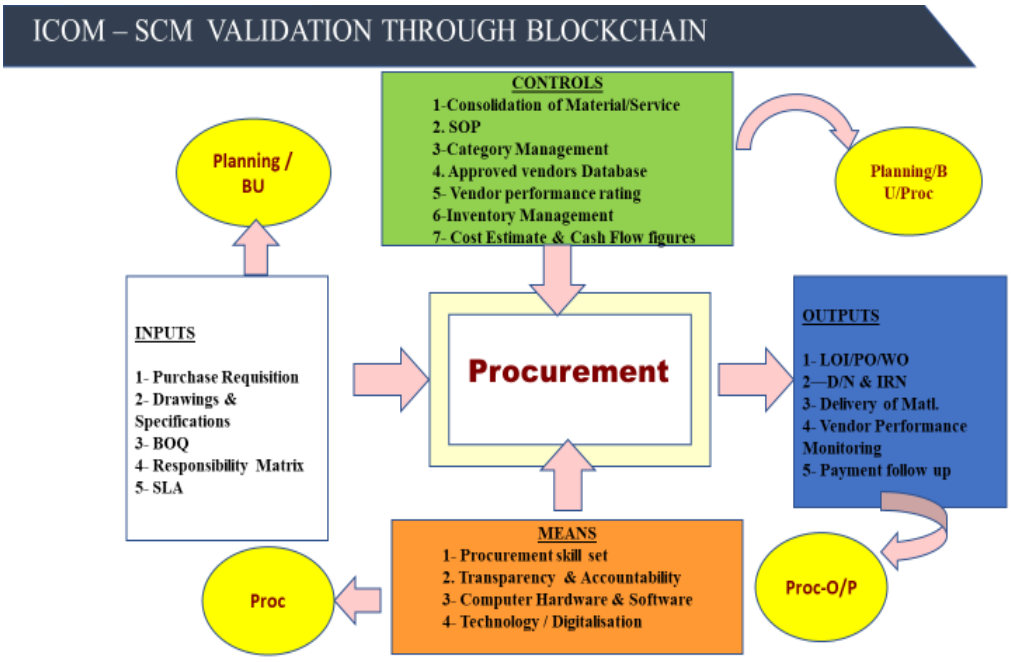


Figure 2.4: ICOM-SCM Validation through Blockchain

Various technologies have been developed to support SCM functions efficiently. Success lies in effective usage of the system that operates quickly and efficiently (Tummala, R. et al., 2006). The various stages of systems enablement are:

- Knowledge, persuasion and decision- gain knowledge about the use of tools and technologies, define Vision for Technology adoption, formulate Strategy for Technology adoption (Ahuja, V. et al., 2010)
- Pre-implementation- Activities include problem identification, need validation, option evaluation and system selection (Bozarth, C., 2006). Decision needs to be taken between development of in-house systems or packaged system available in the market (Forslund, H. et al., 2010)
- Implementation- customization/ customer-specific changes (Forslund, H. et al., 2010)
- Post-implementation- Includes, systems maintenance, supporting users, upgrading and system expansions (Loh, T.C. et al., 2004)

Blockchain can be implemented in the supply chain at two broad levels, as depicted below:

- Transactional Blockchain- secures process and circulate raw data of supply chain and to assemble reports to summarize these data. Enterprise resource planning (ERP), manufacturing resource planning (MRP II), distribution resource planning (DRP), electronic data interchange (EDI), and other e-commerce systems etc. are the right Examples. Analytical Blockchain approaches descriptive and normative models for effective decision making in the organisation. It includes demand prediction, activity baseline costing, developing customer profiles based on point-of-sale data, and various rule-based decision making models, etc.

Supply Chain activities can also be divided into three broad categories (Chang, H.H, 2006; Sahay,

B.S. et al., 2003)

- SCM Planning
- Distribution planning
- Manufacturing planning

- Production Planning
- Supply planning
- Demand forecasting
- Supply chain network design
- Supply Chain Execution (SCE)
- Order management
- Inventory management
- International trade logistics
- Transportation management
- Warehouse management
- Supply chain event management
- Customer-supplier collaboration
- Supply Chain Optimisation (SCO)
- Network optimization
- Inventory optimization

Technology adoption is low among construction companies. Individual construction companies supply to various retailers, thus, construction companies use various technologies which are forced by retailers like Electronic Data Interchange (EDI) (Webster, M. et al., 2006). Some of the software solutions used by construction companies are mobile order taking system, delivery optimization system, routing optimization system and mobile delivery information system.

2.5 Challenges and opportunities in the construction supply chain

Conducted focused group discussion among 12 SCM professionals of a renowned project construction group in hybrid mode to understand the challenges and opportunities in the

construction supply chain, the findings of which are detailed below table.

Table 2.4: Challenges and Opportunities in the Construction Supply Chain

Slackness EPC Contract management acceptance- Quality, Time Management, Project can go on Fast Track Mode
Improper Material reconciliation issue causing piling up of unaccounted stock
Ineffective scrap management
Lack of skill set development plan based on SCM need
Missing lifecycle-based materials management
Unplanned waste management practices
Week focus on sustainability in SCM
Missing transparency in SCM
Unstructured back tracing mechanism of supplies (T1, T2, T3….)
Not much expression of interest through website for participating in SCM
Wide spade cash transaction in contractors or labour payments
Compromised casety parameters
Lack of collaboration among suppliers causing widespread non-compliance
Space is a big constraint
SAP Process Quality Module
Material Management (MOC)
Actual conception booking
Inventory tracking on cost basis
PR is not coming to review for store team
PR should be reviewed by Functional Head rather than divisional head
Project- No material control process
Free issue material management is GAP, no material conciliation
Vikas and Sidhesh participation in aayam project
SAP or Internet problem
No. of transactions are more
repeat transactions are more
MOC procurement - most of the cases Budget Error
Material received and ION closure then user try to link to some other ION (10-15percent) time consume
Commercial to technical handover in VENDX remove the google sheet (30-45 minutes time consume in updating the same for just MIS purpose)
Frequent Guideline Change & Training User (30 -45 minutes consumption of buyer)
Emergency Approval & guideline
Budget Error during PO creation
HSN & BOE document submission - It should be online
Don't have a proper traceability of payment

For small value items, Negotiation link sometimes has to be send multiple time to proper fill the terms and conditions negotiated on phone
BP is not agreeing for low volume and value items to correct in system and buyer has to educate them first, which will take time and BP straight forward deny to do the same in system
Challenges in timely payment release as per contract promise.
Gate entry- freight charges, time consume for unloading, proper documentation of vehicle required, which create problems to BP to select some specific transport agency
Improper planning in Project & MOC
Mismanagement in Advance Payment tracing.
Improper GST calculation because of no HSN code printed with PO
PO issue mail should also go for functional head
Material receipt option should be there even after ION is closed
Import PR- PO system
In OPEX trader to OEM conversion is difficult because of low value and volume item
Procurement booklet - to have a trend of price
MBL for service sourcing
Weekly basis outside SLA report to send with promise action
Improper Quality assurance plan in PO/RFQ
Geeting the realistic expectation
Lab- Multiple philosophy of maintaining inventory
Duplication of approvals (Vendx/SAP)
Ownership of drawing approval
Lack of differentiation between Fast track project requirement and normal project requirement.
Sanity of urgency is missed
More gap in guidelines effective training
Training to new employee (Induction + functional)
System Robustness (SAP) ex. technical packages
Lack of procurement planning
OLA Urgency
Google sheet itself is a problem
PE team, process champinion not utilised in execution
Local liasioning (Jhagadia) is poor
Short closure of PO
Resource utilisation (Urgency)
PO copy reaches late to expediting
Project team don’t invite for kick off meeting
Delay in approval in QAP
Scope change in PO after release
Numbers of meeting is quite high
Dispatch clearance by site team

Challenges in capturing the Change in need date causing huge impact on suppliers.
Sustainability & governance
Lack of transparency in MSME tracking
Mismanagement in LD calculation for deduction
Absence of Contract closer

2.5.1 Factors Affecting Implementation of Blockchain enabled Supply Chain

Research is scarce and fragmented in the area of critical success factors (CSFs) affecting Blockchain- enabled Supply Chain and better understanding is needed for successful implementation (Denolf, M.J. et al., 2015). Factors affecting implementation of Blockchain have been investigated by many researchers and are listed in table 2.5.

Table 2.5: Critical Success Factors

S.No	Factors	Literature Review
1	Client Related	• Blockchain technology in supply chain management: an empirical study of the factors affecting user adoption (Moutaz Alazab, S.A. et al., 2021) • Effect of User Involvement in Supply Chain Cloud Innovation: A Game Theoretical Model and Analysis (Yun Chen, W.Z. et al., 2020) • User-driven supply chain business model innovation: The role of dynamic capabilities (Yanhua Sun, Y.G. et al., 2021) • Sustainable Supply Chain Management and the End User (Brian Gillespie, M.R. et al., 2016) • Employees play a major role in the implementation

		(Shaaban, M.S. et al., 2014; McMullan, A., 1996)
2	Contract Management Related	• The Potentials and Impacts of Blockchain Technology in Construction Industry: A Literature Review (Kiu Mee San et al., 2019) • Automated Payment and Contract Management in the Construction Industry by Integrating Building Information Modeling and Blockchain-Based Smart Contracts (Katharina Sigalov, X.Y. et al., 2021) • A Blockchain-Driven Electronic Contract Management System for Commodity Procurement in Electronic Power Industry (L. Guo, Q. L. et al., 2021) • Blockchain technology and cryptocurrency are databases for contract management in construction engineering (A Boonpheng, W.K. et al., 2021)
3	Supplier Related	• Improving Vendor-managed Inventory Strategy Based on Internet of Things (IoT) Applications and Blockchain Technology (Tom Dasaklis, F.C. et al., 2019) • Financial strength, industrial knowledge and experience based strength of software vendors need to be considered

		while selecting the Supply Chain package (Sahay, B.S. et al., 2003) • Each partner tries to maximize individual interests instead of collaborative interests (Park, S.H. et al., 2001) • Strength of a supply chain linkage depends on the level of "trust", "adaptation", "communication" and "cooperation" present between partners within the supply chain (Fynes, B. et al., 2005) • Organizations don't want to share information with trading partners (Lee, H.L. et al., 1997) • Selection of optimal supplier in supply chain management strategy with analytic network process (KC Tan, V.K. et al., 2009) • The impact of supply chain structure on the use of supplier socially responsible practices (A Awaysheh, R.K. et al., 2010) • The selection of proper implementation team along with external consultants is essential for effective implementation(Upadhyay, P. et al., 2011)
4	Planning and Compliance Related	• Managing demand uncertainty in supply chain planning (A Gupta, C.M. et al., 2003) • A BIM-based Construction Supply Chain Framework for Monitoring Progress and Coordination of Site Activities

		(Vito Getuli, Silvia Mastrolembo Ventura, Pietro Capone, Angelo L.C. Ciribini et al., 2016) • Compliance, network, security and the people related factors in Digital implementation (Shivam Gupta, S.M. et al., 2016) • Enterprise Resource Planning Systems Affect Firm Risk (F Tian et al., 2015)
5	Unethical Practice Related	• Misalignment of motives and behaviors among allying partners within the strategic supply chain (Park, S.H. et al., 2001) • Implementation requires users to change the ways of working (Sandhu, M. et al., 2012) • Information security and lack of legal framework is a majorbarrier in adoption of IT (Kannabiran, G. et al., 2012) • A major barrier for implementation and adoption of IT isthreat of information security (Borade, B.A. et al., 2010)

2.5.2 Success Indicators

Success is a complex concept and its definition changes as per the stakeholders and the phase of project life cycle (Sun, Y. et al., 2009; Jugdav, K. et al., 2005). A lot of research has been donein defining 'Success Indicators' (Ram, J. et al., 2013; Maditinos, D. et al., 2011; Agarwal, N. et al., 2006; Jugdev, K. et al., 2005; Delone, H.W. et al., 2003). 'Success Indicators' can be classified into three broad parameters- people, process, and tools (Maryska, M.et al., 2017). A brief synopsis of existing literature has been listed in table 2.6.

Table 2.6: Success Indicators

S.No	Success indicators	Literature Review
1	Social Bottom-line	• Blockchain technology for social impact: opportunities and challenges ahead (Walid Al-Saqaf, N.S. et al., 2017) • From Good Governance to Governance for Good: Blockchain for Social Impact (Elham Seyedsayamdost, P.V. et al., 2020) • Incompetence to appreciate and understand promised advantages (Sun, H. et al., 2015; Ahmad, N. et al., 2014; Kositanurit, B. et al., 2006) • Implementation success depends on the ease of use of the system (Dmaithan, A.A. et al., 2016; Nwankpa, J., 2015; Venkatesh, V. et al., 2003) • Digital implementation has significant impact on labor productivity (Mukhopadhyay, T. et al., 1997)
2	Economic Bottom-line	• A critical analysis of the advantages brought by blockchain technology to the global economy (Eva Raquel Porras-Gonzalez et al., 2019) • How blockchain technologies impact your business model (Vida J. Morkunas, J.P. et al., 2019) • One of the critical measures of Digital system is the level of adaptation (Delone, H.W. et al., 2003; Lancioni, A.R. et al., 2003)

		• Blockchain Economic Networks: Economic Network Theory (Melanie Swan et al., 2018)
3	Environment Bottom-line	• The Effect of Blockchain Technology on Supply Chain Sustainability Performances (Arim Park, H.L. et al.,2021) • Sustainable supply chain management: Review and research opportunities (Sudheer Gupta et al., 2011) • Environmental and sustainability ethics in supply chain management (Benita M. Beamon et al., 2005) • Relationships Between Environmental Impacts and Added Value Along the Supply Chain (R Clift, L.W. et al., 2000) • Green supply chain management practices and the impact on environmental performance (Anwar Al-Sheyadia, L.M. et al., 2019)

2.5.3 Firm Performance Measures

Performance Measurement process is defined as

"As the process of quantifying the efficiency and effectiveness of action" (Neely, A. et al., 1995)

"Development of indicators and collection of data to describe, report on, and analyze performance" (Marshall, M. et al., 1999)

"Yardsticks that tell us, how we have done and motivate us to perform better" (Najmi, M.et al., 2001)

"a collection of related activities designed to identify and collect data and transform them into relevant, understandable and actionable information that allows accurateassessment of the extent to which strategic, tactical and operational objectives have been achieved and forms the basis of reward and appraisal systems". (Kuwaiti, E.M., 2004)

" is lifeline to organizations' vision, and strategy by providing specific measurable expectations that guide each employee in fulfilling their roles that contributes to the success of the organization" (Choong, K.K., 2013)

Performance Measure has the following characteristics

- Derived from strategy and clearly defined (Globerson, S., 1985)
- Have an explicit purpose (Globerson, S., 1985)
- Transparent and simple to understand (Lea, R. Et al., 1989)
- Provide timely, accurate, precise and objective information (Fortuin, L.,1989)

- Focus on improvement rather than variance (Lea, R. Et al., 1989)

- Quantitative and inclusive in nature (measurement of all pertinent aspects) (Beamon,M.B., 1999)
- Include an effective mechanism for reviewing and revising targets and standards (Najmi,M. Et al., 2005)
- Measures Efficiency, Effectiveness, Quality, Timeliness and Productivity (Choong, K.K., 2013)

  In order to understand organizations' performance, it is necessary to measure, monitor, control and manage things and processes (Taticchi, P. et al., 2010). Performance measures should be reviewed and modified once new operational systems are put in place or new opportunities emerge (Najmi, M. et al., 2005). Previous research supports that firm performance outperforms with technology implementation (with most of this being focused on implementation of ERP) capability (Kaur, M. et al., 2013; Gunasekaran, A. et al., 2001; Bharadwaj, A.S., 2000; Handfield, B.R. et al., 1999; Mukhopadhyay, T. et al., 1997).

  Various performance measure tools have been developed

- Balanced Score Card (BSC) (Kaplan, S.R. et al., 1996)
- Three level frameworks for metrics development for Supply Chain Performanceevaluation (Gunasekaran, A. et al., 2001)
- Four level of integrated Supply Chain- plan, source, make and deliver (Stewart, G.,1995), Supply Chain Operations Reference (SCOR) Model (Huan, H.S. et al., 2004)
- Framework integrating features of BSC and SCOR (Thakkar, J. et al., 2009)

A brief synopsis of existing literature review of the firm performance measures have been listed in table 2.7.

Table 2.7: Performance Measures

S.No	Performance Measures	Author and Year
1	Return on Investment	Hitt, M.L. et al., 2002; Gunasekaran, A. et al., 2001; Stewart, G., 1995
2	Net Profit	Evelyne, V. et al., 2017; Hitt, M.L. et al., 2002; Gunasekaran, A. et al., 2001
3	Value to Shareholders	Gunasekaran, A. et al., 2004; Neely, A. et al., 1995
4	percent Market Share	Thakkar, J. et al., 2009; Neely, A. et al., 1995
5	Customer Satisfaction	Christiaanse, E. et al., 2000
6	Net Profit vs. Productivity Ratio	Gunasekaran, A. et al., 2001
7	Total Cycle Time	Chae, K., 2009; Towill, D.R., 1997
8	Rate of Return on Investment	Gunasekaran, A. et al., 2001
9	Cost per Operation Hour	Thakkar, J. et al., 2009; Gunasekaran, A. et al., 2001
10	Information Carrying Cost	Gunasekaran, A. et al., 2001
11	Return on Capital Employed	Nielsen, S. et al., 2008; Padachi, K., 2006
12	Cash-to-Cash Cycle	Chae, K., 2009; Farris, T.M. et al., 2002; Stewart, G, 1995
13	Inventory Days of Supply	Chae, K., 2009; Stewart, G., 1995
14	Inventory Turns	Chae, K., 2009; Blankley, I.A. et al., 2008; Hitt, M.L. et al., 2002
15	Total Supply Chain Inventory	Chae, K., 2009

16	Capacity Utilization	Chae, K., 2009; Gunasekaran, A. et al., 2004
17	Order Fill Rate	Chae, K., 2009; Stewart, G., 1995
18	Order Lead Time	Une, R.P. et al., 2014; Stewart, G., 1995
19	Delivery Lead Time	Chae, K., 2009
20	Time-to-Market	Huan, H.S. et al., 2004; Datar, S. et al., 1997;Pawar, S.K. et al., 1994
21	Forecast Accuracy	Thakkar, J. et al., 2009; Chae, K., 2009
22	Order Track and Trace Performance	Yoo, J.S. et al., 2004; Kumar, D., 2003
23	OTIF (On-Time In-Full)	Une, R.P. et al., 2014; Otto, A. et al., 2003
24	Number of Stock Outs	Otto, A. et al., 2003

2.6 Research Gaps Arising from Literature Review

1. The most important issues hindering the transformation of the construction industry is its inability to adopt technological advancements in comparison with successes seen in logistics, automotive and engineering industries. Research relating to the digital revolution of the construction industry in a technologically advanced era is not reported in the academic literature.
2. Smart contracts minimize the transaction cost and enhance the trust between contract parties, however research related to scope of their implementation in construction supply chain management are thinly reported.
3. A synthesis of knowledge regarding the success indicators of smart contracts and their effect on performance is not found in the literature.
4. Contribution of smart contracts and blockchain technologies banking as well as healthcare industry are widely researched however their potential impact on construction supply chain management have not been discussed in academic literature.
5. Timely payment is another biggest problem in construction industry. Entitlements are paid late, not being paid at all or being held up as a result of disputes which can often result in project

delay and business crash. Smart contract helps in defeating these problems, however no credible research is found catering these issues.

2.7 Conclusion

The literature review has highlighted that traditionally construction industry is not the front runner in adopting emerging technologies. This lethargic approach is predominant across the construction /infrastructure companies restricting the rapid growth in this industry segment. Even if some of the construction companies adopt advanced technology, the same doesn't excite others avoiding investment with look ahead approach. Moreover, supply chain management in construction industry by and large are considered as cost center and any investment proposal are scrutinized under magnifying glass. Blockchain technology is in a nascent stage and has not been advocated by construction supply chain for value unlocking where the opportunities are unlimited. During the challenging situation in recent past, the term Supply Chain gathered momentum as the entire would understand the importance of it. In order to save substantial time and cost required for implementing Blockchain technology enabled Supply Chain in construction segment, organizations are focusing on identifying Critical Success Factors (CSF). Also, studies have highlighted how Blockchain technology implementation has improved the firm performance.

The gaps identified in the existing literature have motivated the authors to carry out current research work. The next chapter focuses on the research methodology particularly how using literature review and focus group discussion with industry experts, "CSFs", "Success Indicators" and "Performance Measures" have been identified.

Chapter 3

RESEARCH METHODOLOGY

The chapter outlines the methodology adopted for the current research. It details the complete research methodology process along with the need for the study. The gaps are then mapped to research questions and objectives. Thereafter, focus group discussion is used to identify the constructs and measurement items followed by questionnaire design, validation & finalization along with data collection and validation. Finally, research model is formulated along with the hypothesis that needs to be tested.

3.1 Research Gap

A lot of research has been done in identifying CSFs impacting Blockchain implementation, success indicators and firm performance measures. From the literature reviewed, it is evident that there is scarcity of research done in Blockchain enabled supply chain and focus has not been Indian construction sector. Thisresearch addresses the gap identified from literature review.

3.1.1 Research Objectives

1 To identify areas where the blockchain provides the most value for construction supply chain management.

2 To identify drivers, barriers, and risk to blockchain deployment within construction supply chains management.

3 To explore the factors influencing the deployment of smart contracts as well as their success indicators in Indian construction supply chain management.

4 To evaluate the impact of critical factors on effective implementation of smart contract in construction supply chain management.

5 To evaluate the effect of smart contracts on performance of the construction supply chain management.

Table 3.1: Mapping of Research Gaps, Research Questions and Research Objectives			
S. No.	**Research Gaps**	**Research Questions**	**Research Objectives**
1.	One of the main issues hindering the modernisation of the construction industry is its inability to embrace technological advancements in comparison with successes seen in logistics, automotive and mechanical engineering industries. Research relating digital transformation of the construction industry in technological advanced era are not found in reported in the academic literature.	How will the blockchain influence future supply chain practices and policies of Indian construction industry?	To identify areas where the blockchain provides the most value for construction supply chain management
2.	Smart contracts minimize the transaction cost and enhance the trust between contract parties, however research related to scope of their implementation in construction supply chain management are thinly reported.	What are the drivers, barriers, and risk in implementing the blockchain technology within the construction supply chain management?	To identify drivers, barriers, and risk to blockchain deployment within construction supply chains management.
3.	A synthesised knowledge regarding the catering the success indicators of smart	What are the factors influencing the deployment of smart	To explore the factors influencing the deployment of smart

	contract and their effect on performance is not found in the literature.	contracts in Indian construction supply chain management?	contracts as well as their success indicators in Indian construction supply chain management.
4.	Contribution of smart contracts and blockchain technologies banking as well as healthcare industry are widely researched however their potential impact on construction supply chain management have not been discussed in academic literature.	What are the success indicators which measured the implementation of smart contracts in Indian construction supply chain management?	To evaluate the impact of critical factors on effective implementation of smart contract in construction supply chain management.
5.	Payments are one of the construction industry's biggest problems with regards contractual entitlements being paid late, not being paid at all or being held up as a result of disputes which can often result in business failure. Smart contract can help in overcoming these problems, however no credible research is found catering these issues.	How will effective implementation of smart contracts affect the performance of the construction supply chain management?	To evaluate the effect of smart contracts on performance of the construction supply chain management.

3.1.2 Methodology

Table 3.2: Qualitative and quantitative tools to achieve the proposed objective		
S. No.	**Research Objectives**	**Tool Used/ Methodology adopted**
1.	Chapter 1: Introduction To identify areas where the blockchain provides the most value for construction supply chain management	Literature review and focussed group discussion
2.	Chapter 2: Literature review To identify drivers, barriers, and risk to blockchain deployment within construction supply chains management.	Literature review and focussed group discussion
3.	Chapter 3: Research Methodology To explore the factors influencing the deployment of smart contracts as well as their success indicators in Indian construction supply chain management.	Literature Review/ Semi-structured Interviewee
4.	Chapter 4: Data Analysis To evaluate the impact of critical factors on effective implementation of smart contract in construction supply chain management.	Statistical Analysis: Exploratory Factor Analysis (EFA) & Structural equation modeling (SEM)
5.	Chapter 5: Result & Discussion To evaluate the effect of smart contracts on performance of the construction supply chain management.	Hypothesis Testing

a. Research Framework

The research framework flowchart has been described in figure 3.2, stating all the steps that have been followed

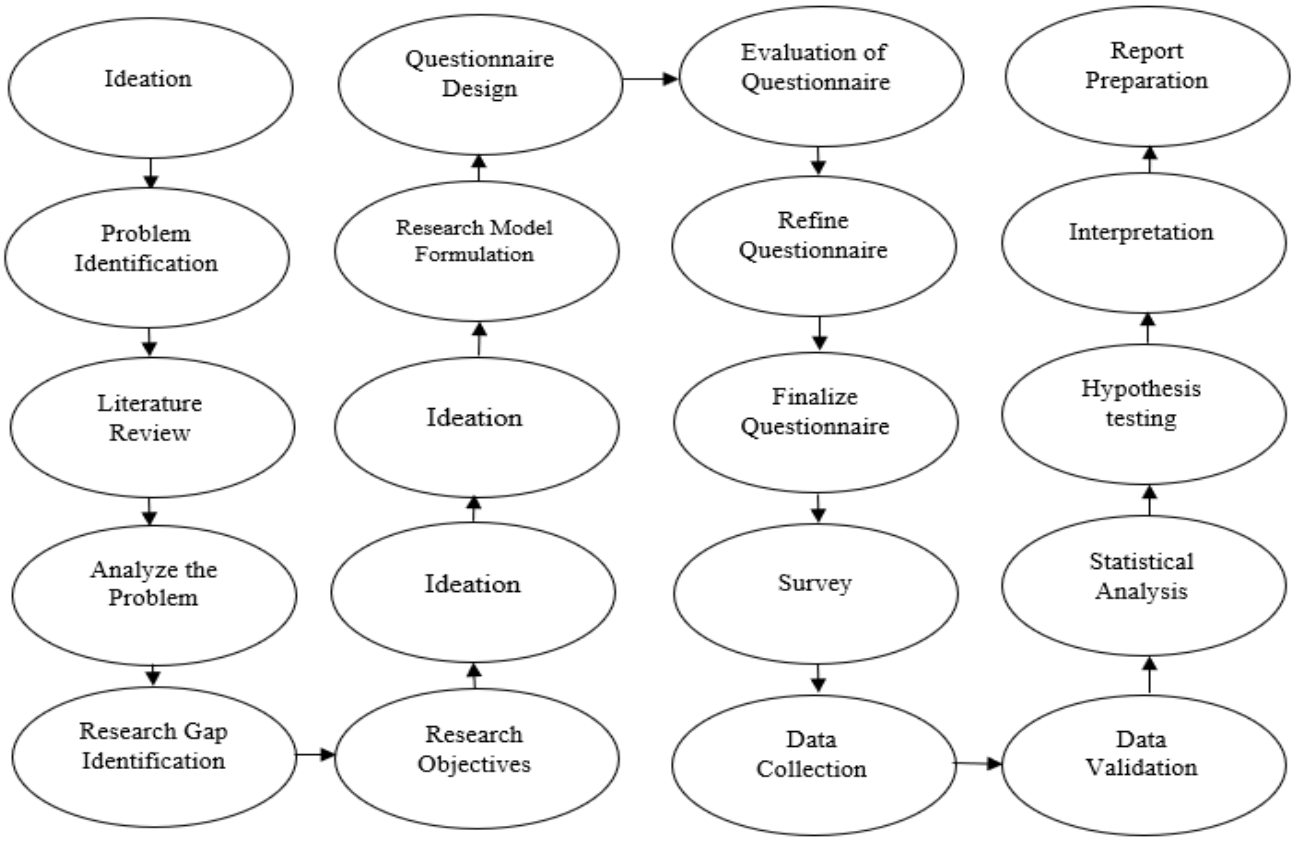


Figure 3.2: Research Framework Flowchart

The following methodology has been used

- Identification of CSF constructs, success indicators and performance measures for implementation of Blockchain technology enabled supply chain in Indian construction sector through detailed literature review and expert opinion
- Questionnaire based survey to establish the impact of CSFs on Blockchain technology enabled supplychain and performance of organisation.
- Construction/Infrastructure industry in India is the target industry for survey

- Sample selection: The sample has been selected from the following databases- Supply Chain professionals in Indian construction industry, alumni working in construction industry.
- The following statistical tests have been conducted
- Content validity of questionnaire
- Construct validity of questionnaire
- Reliability Test
- Descriptive statistics
- Exploratory Factor Analysis (EFA)
- Confirmatory Factor Analysis (CFA)
- Structural Equation Modeling (SEM)

b. Scope of Present Research

The research scope in this case is restricted to businesses operating in Indian construction/chemical industry. The study is done in across the country. The departments covered are Procurement, Supply Chain, Manufacturing, Business Development, Management Control, Production, Service & contracts. The people selected for survey in these organizations are either APICS certified professionals – ('Certified Supply Chain Professional' (CSCP) & 'Certified in Production and Inventory Management' (CPIM)) or NITIE (National Institute of Industrial Engineering) alumni.

c. Focus Group Discussion

Post the extensive literature review 'CSFs', 'success indicators', 'performance measures' & 'level and extent of Blockchain Technology usage' have been identified. In order to finalize the constructs along with measurement items, focus group discussion was conducted. The members chosen for this discussion consists of 46 Construction SCM experts. In the first step,

comprehensive list of CSFs, success indicators, performance measures and level and extent of IT usage was communicated via mail so that they can come prepared in the focus group discussion. After 10 days, discussion took place for 3 hours, so as to capture the constructs and measurement items. In the second step, 11 workshops of 2 hours each were conducted involving 165 Construction Industry professionals to understand and capture their understanding of blockchain technology and how can this be implemented in construction SCM for creating a sustainable supply chain ecosystem. After consolidating the conclusion of focus group discussion and workshops, comprehensive list of constructs and measurement items were shared again with the members and 3 academicians in addition for their final review.

The final outcome, in terms of constructs and measurement items is presented into the below sub-section.

Table 3.3: Construction Supply Chain Sustainability Virtual Workshop

Construction Supply Chain Sustainability Virtual Workshop					
Sr. No	**Workshop Details**	**Date**	**No of Partners proposed**	**Number of partners Invited**	**Number of partners Attended**
1	Workshop-1	03-03-2021	25	25	14
2	Workshop-2	05-03-2021	25	36	10
3	Workshop-3	17-03-2021	25	97	31
4	Workshop-4	19-03-2021	25	67	13
5	Workshop-5	23-03-2021	21	54	6
6	Workshop-6	26-04-2021	47	47	28
7	Workshop-7	24-05-2021	19	19	10
8	Workshop-8	28-06-2021	9	9	3
9	Workshop-9	17-12-2021	23	23	19
10	Workshop-10	14-01-2022	23	27	14
11	Workshop-11	11-02-2022	23	36	17
Total			**265**	**440**	**165**

Table 3.4: Areas where the blockchain provides the most value for construction supply chain

Non-linking of materials/services requirements with project critical path (CPM)	Client/user related
Fragmented purchases causing high percentage of emergency procurements	
Absence of category management	
Ineffective stakeholder management	
Lack of sense of accountability	
Lack of differentiation between Fast track project requirement and normal project requirement.	Contract Management related
Improper Material reconciliation issue causing piling up of unaccounted stock	Planning/Process Compliance related
Missing lifecycle based materials management	
Week focus on sustainability in SCM	
Unstructured back tracing mechanism of supplies (T1, T2, T3…..)	
There is widespread non-compliance to standard operating procedures (SOP)	
Absence of 'need validation'	
Improper GST calculation because of no HSN code printed with PO	
Compromised safety parameters	Safety/Social/HR related
Data is still people-dependent,	
Lack of Global strategic mindset	
Inadequate training on the given assignment	
Inadequate automation	
Frequent Guideline Change leads to repetitive training to user	
Inadequate Resource utilization	
Inadequate Sustainability & governance	
Not much expression of interest through website for participating in SCM	Supplier/contractor related
Lack of collaboration among suppliers causing widespread non-compliance	

Delayed submission of offer by suppliers	
Mismanagement in Advance Payment tracing.	
Lack of transparency in MSME tracking	
Frequent Budget Error during PO creation	System related
Incorrect Harmonized System of Nomenclature (HSN) code & basis of estimate (BOE) document submission - It should be online	
Absence of SCM Dashboard	
Sluggish data integrity and security	

Table 3.5: Drivers, barriers, and risk to blockchain deployment within construction supply chains

Missing quality/labour/HSE policy in PO/WO	Client/user related
Lack of consolidated procurement plans	
Poor understanding of working capital/cash flow management at operating level	
Week escalation matrix	
Absence of Contract closer	Contract Management related
Unplanned waste management practices	Environment related
Over loaded transportation of goods compromising environmental norms	
Improper identification of shelf life/hazardous materials	
Ineffective scrap management	Planning/Process Compliance related
Missing transparency in SCM	
Lethargic exercise of inventory management	
Lack of status updates	
Huge No. of repeat transaction	
Improper planning in Project & Management Of Change (MOC)	
Multiple philosophy of inventory management	
Absence of standard formats and checklists across the organisation	
Lack of skill set development plan based on SCM need	Safety/Social/

Unauthorised application of equipment	HR related
Poor Local liasioning	
Monopolistic approach of suppliers	Supplier/contractor related
Cartelisation by suppliers/contractors	

Abnormal delay in drawing approvals by the client or principle contractors	Client/user related
Deferment of supplies/inspection by the client/owner causing capital blockage of supplier	
Inadequate scope sharing by user	
Slackness in EPC Contract management acceptance- Quality, Time Management, Project can go on Fast Track Mode	Contract Management related
Lack of periodic contract performance management	
Supply of non-standard & sub-standard materials/services	
Improper Quality assurance plan in PO/RFQ	Planning/Process Compliance related
Delayed PO copy circulation to internal stakeholders	
Widespread cash transaction in contractors or labour payments	Safety/Social/HR related
Sloppy collaborations & trust even among the internal stakeholders	
Indulging in ethical practices by suppliers/contractors	
Very high numbers of meetings	
Improper traceability of payment	Supplier/contractor related
Challenges in timely payment release as per contract promise.	
Frequent Scope change by user in PO even after release	
Mismanagement in LD calculation for deduction	

i. Constructs and Measurement Items for Blockchain enabled Supply Chain

Table 3.2 highlights the constructs and measurement items impacting Blockchain enabled supply chain

Challenges in SCM related to client/user (CLR).

Out of the major challenges in SCM, the reason of most of them relates to User or Client. Starting from the unclear need to the timely payment to the supplier, the entire journey is full hurdles.

Unfortunately, most of the cases, the poor supplier becomes the runner from pillar to post and the user or client plays the role of umpire in this unrealistic blame game. This age-old practice not only makes the supply chain inefficient, but also adds a huge cost of trust.

The journey starts with the unclear need: Many a times, the user doesn't know what exactly the project needs and when. If the basic is unknown, obviously the scope will certainly be a grey area. As a result, the scope keeps on changing and the same continues even after placement of PO/WO.

Since the materials/services are usually not linked to the project critical path, the materials are ordered with earliest available delivery timelines. Even the supply of materials and services are expedited without valid reason adding huge unknown cost of insurance.

When the project management realises that the ordered material is not required as anticipated, they try to delay the inspection and or delivery causing stock pile up at supplier's end. If deferment doesn't work, delivered materials gets piled up at user's end.

In both the cases, the working capital gets blocked at either end which ultimately gets added into the project cost or the supplier bears the loss and starts delaying the other supplies in the same project or other projects. This way, the impact of miss-planning cascades down and blame game continues.

Generally, in India, the project organisations lack in planning of annual requirements. The materials or services are ordered on piecemeal basis with the delivery expectations of yesterday. In the process, same items are ordered time again in the same project relinquishing the scope of effective negotiations, rate contract, volume discount, timely & phased delivery, resource optimisation and sustainability.

Similarly, some project materials are delayed owing to scope finalisation, late ordering, deferred drawing approval, weak stakeholder management, missing quality policy etc. Ultimately, the delay in delivery of those items causes following effect in the construction project:

- Stockpile up of other items which has been delivered as per schedule

- Expiration of warranty for capital items
- Challenged inventory management
- Expiration of shelf life
- Increase in percent wastage and or disposal
- Delay in payment to the suppliers
- Non-compliance of contract deliverables and integrity

A recent in-house study amid different construction projects in a speciality chemical industry indicates only 24percent of POs (181 Nos) have been delivered within the contractual delivery date (CDD), whereas 90percent of the POs delivered after CDD, but within the need date (ND). That means, the gap between CDD and ND is high and unwarranted. The same could have been avoided through proper planning to make the project more profitable and supply chain more efficient.

Challenges in SCM related to client/user- Possible solutions through Blockchain Technology (BLT)

Blockchain being the decentralised digital ledger network, all the stakeholders starting from the owner/user to the supplier or contractor can be easily taken into this network primarily to establish a trustworthy business environment where every stakeholder shall be able to operate with confidence and without having any threat of losing.

Once the major hurdle is taken care of by the digital technology, the other gaps can be bridged without many challenges. The stakeholders will know that whatever commitment they give to the other member in the network shall be stored in a particular block. Everyone in the network can see the commitment/data of others but cannot alter even the slightest. In case of failure of fulfilling the commitment or new promise date or change request of the earlier scope, a new set of data/commitment can be generated in a new block without any impact on the previous block. Even in case of consensus of respective stakeholders, the same protocol will be followed and the earlier block data will remain unchanged. This will bring discipline in the business environment and strengthen the sense of accountability at every level of commitment.

Accountability will ensure more and more transparency at every transaction level. People will be forced to avoid judgemental approach and will be encouraged to exercise data supported decision making. When the decisions are data supported, the accuracy level will drastically improve.

Higher accuracy will trigger higher quality at every transaction level and improve the efficiency of SCM.

To maintain the data integrity in a particular business network, permissioned blockchain would be most effective. In this protocol, the stakeholders/business partners will need permission to join the blockchain network, but it will maintain a decentralised digital data management system among the participating members.

Challenges in SCM related to Contract Management (CMR)

Contract Management in India is still in its growth stage. Proper understanding of contractual terms, its implementation, measuring the gap between the deliverables & delivered are not professionally handled in most of the cases. The initiation of corrective measures to bridge the gap gets delayed and the project faces unnecessary time & cost overrun as a result. This is undoubtedly a major area of concern and a vital area of improvement.

Still the age-old concept of "manageable at the later stage" drives the contract management instead of time sensitive professional approach.

Construction Industry by design and description is less disciplined and organised worldwide compared to manufacturing and process industries.

In construction industry, most of the organizations suffer losses or compromise profitability because of the ineffective and inefficient contract management.

Worldwide, the construction sector is considered as one of the top contributors in Gross Domestic Product (GDP). It encompasses a wide range of actions involving modern transport engineering, major road projects, challenging bridge constructions, highly sophisticated sculptures, complex infrastructure projects, sensitive atomic power plants, delicate chemical plants construction, environment friendly engineering projects, commercial and residential complexes to name a few. The construction business holds a significant connections with other industry sectors, therefore, its influence on GDP and economic growth goes further than it's direct contribution to construction activities alone.

Indian construction (project/infrastructure) sector is very successful in attracting high foreign direct investment (FDI), placing the segment among the top ten. FDI influxes in construction industry sector including infrastructure has climbed a new height in couple of years to USD 2258 million from USD 1861 million. Even the union government increased its expenditure in 2018-2019 budget, towards infrastructure development by around 21 percent - from USD 76

billion in the Financial Year (FY) 2017-2018 to USD 89 billion in FY2018-2019. In the Global Construction 2030 report, Price Water Coopers (PWC) forecasted, by 2030 the global volume of construction output is expected to grow by 85 percent to USD 15.5 trillion majorly in three countries- India, China, US. India is going to lead the way accounting for 57 percent of worldwide growth (source: © Nishith Desai Associates 2020, www.nishithdesai.com).

Low value of commitments plays a detrimental role in Indian construction industry. Both the parties (contractor & owner) expect fulfilment of commitments by the other without discharging the responsibility of the self as worded in the contract.

Due to the unknown reason, both sides go on violating the contract commitments, take the strategy of wait and watch keeping the disputes pending for tomorrow. Finally, they flag off declaring "stop of work" at the end of their sustainable limit. This types of disputes in construction contracts are conspicuously different from other contracts and has become a legacy issue. As these are very much technical and complicated in nature, it calls for an insistent resolution most of the time involving all the stakeholders. This game theory goes on without any tangible benefit to any of them making the contract management more vulnerable.

Diving deep into this will open up the area of lack of discipline and non-adherence of standard operating process. Generally, construction contracts in India are finalised over a lengthy multiple and multilayer negotiations, but minutes of meetings are not made in most of the cases. Finally all the concerns are not captured in the contract may be with the understanding or anticipation of managing those informally and those becomes the point of dispute in later stage at the execution level. One more major reason of such disputes are owing to the lack of coordination between the business development team and execution team. Both works for their individual targets in isolation sacrificing the larger interest of the organisation.

Some of the common areas of disputes in contract management are as follows:

- Unclear specifications, BOQ (bill of quantity)
- Lack of detailed drawing or timely drawing approvals
- Compliance of organisational policies on labour, safety, quality, POSH (prevention of sexual harassment at work), environment, CSR (corporate social responsibility), sustainability, etc.
- Feeble responsibility matrix, governance mechanism and feedback which became more prominent during the present pandemic situation.

Ultimately, the above lose ends make the contract weak and unworkable causing unnecessary

time and cost overrun.

Challenges in SCM related to Contract Management - Possible solutions through Smart contract

Most of the cases, the contract management fails because of the lack of governance. The organisations or project management does not pay required attention to the governance mechanism allowing the deviations leading to slower delivery, intermittent stoppage of work, time & cost overrun, finally litigations and involvement of third party for resolution at further extra cost.

SMART contract can be a very effective tool to the contract management even without involving any intermediatory. Right at the moment the legal standing of smart contract in India is bit unclear, but when Indian Banking sector governed by Reserve Bank of India started adopting blockchain and SMART contracts in their transformation journey, the enforceability of the same by law would be a matter of time. Eleven leading Indian banks like Axis Bank, Yes Bank, HDFC Bank, ICICI, South Indian Bank, Kotak Mahindra Bank formed a consortium to manage their loan system to the MSME sector through Blockchain-Smart contract. State Bank of India (SBI) is connected to this consortium as outside partner. SBI also rolled out Smart Contract as their Know Your Customer (KYC) solutions and this evolves as an encouraging factor to the Indian industry.

Smart contract is a self-managed agreement between two or more agencies where the terms & conditions (T&C) are codified in a trustworthy, immutable, distributed, decentralised ledger based on blockchain network.

Beauty of smart contract is, once released, even the creator or owner cannot change the any T&C contract. Each transaction is recorded and executed completely on paperless digital platform without any manual intervention, thus it is time effective and environment friendly. Transactions once done, cannot be reversed. Most importantly, the payment flows as per the agreed T&C and strengthen the trust among the engaged parties.

To make it more simple, smart contract is a computerised digital protocol which governs, verifies, facilitates, modulates and enforces the agreed T&C of an agreement without the intervention of any intermediatory.

2014 onwards the Ethereum based smart contracts started getting momentum. Because of the transparency of Ethereum based digital technology, the smart contract gained trustworthiness.

The cost benefit analysis suggests, smart contract is one of the most times & cost-effective technology going forward.

Challenges in SCM related to Unethical practices (UPR)

Three bottom line is the business performance measurement tool commonly used the industry in the modern era. In today's world, the performance of any organisation is no more limited to its financial bottom-line alone. Compliance of environment wellbeing is also one of the vital measurable key performance area (KPI) to the organisation.

Unfortunately, still the awareness is largely missing in the supply chain community causing severe compromise in this area. A major reason of this negligence could be of our understanding or consideration of environment as an undemonstrative stakeholder.

Today's most of the challenges the human civilisation is facing because of the annoying behavior of environment are the result of such unrealistic consideration over centuries. Global warming, air pollution, poor ground water recharge or ground water contamination are few examples. Dr. Li (Chinese Virologist) and many other people say the present Covid-19 pandemic may be another example of irresponsible innovation of human being which brutally impacted the civilisation and caused unprecedented damage to the supply chain environment.

Unplanned waste management in the project construction site is a very common phenomenon noticed by many of us. These unplanned wastes (construction materials, chemicals, paints, scraps etc.) not only contaminate air & water but also leave a severe health threat to the people at work in the projects and nearby inhabitants.

The categorisation of wastes and preservation of those in specific bins in demarcated areas in a planned way eliminate the above cited threats and facilitate easy disposal at regular intervals saving cost to the project.

Different types of hazardous materials are used in projects and many of them have specific shelve life. Unplanned and unregulated disposal of the same may cause severe counter productive effect to the environment. Those types of materials mandatorily need disposal action in the environment friendly way as per the guideline of manufacturer.

The project management just cannot discharge their responsibilities by maintaining the recommended waste management in their project premises. They need to carry out periodic

audit to their stakeholder's community. Reward them, educate them in case of non-compliances, partner them in developing the required processes to ensure that their suppliers and contractors also follow the same values of waste management participating in a sustainable supply chain ecosystem.

Unburnt hydrocarbon (fuel) is one more concern in construction supply chain management, the trucks and other equipment used in Indian project logistics and supply chain are very frequently overloaded in unlawful way for short term benefits compromising the interest of environment and safety.

Challenges in SCM related to Unethical practices- Possible solutions through Blockchain

The most common construction supply chain challenges related to environment are as follows:

- Unplanned waste management practices
- Ineffective scrap management
- Week focus on sustainability in SCM
- Over loaded transportation of goods compromising environmental norms
- Improper identification of shelf life/hazardous materials

The root cause of the above cited challenges are lack of discipline and governance.

Defining some SMART KPI(specific, measurable, achievable, relevant & time bound key performance indicators) then manage them on a digital platform can definitely bring the transformation in construction supply chain management.

Three bottom line is the business performance measurement tool commonly used the industry in the modern era. In today's world, the performance of any organisation is no more limited to its financial bottom-line alone. Compliance of environment wellbeing is also one of the vital measurable key performance area (KPI) to the organisation.

Defining some SMART (specific, measurable, achievable, relevant & time bound) key performance indicators (KPI) and manage them on a digital platform can bring the transformation in construction supply chain management. Creation of a Learning Platform on Hyperledger Fabric (Distributed Permissioned Blockchain) for imparting vocational training to Construction Workers for Skillset Development and knowledge transfer on the following areas.

- Modern construction technology
- Pre-cast construction technology

- Sustainable construction methods
- Lean construction techniques
- Construction safety
- Construction excellence
- Waste management
- RFID tracking of productivity
- Governance and Identity Management (IM) by using Aadhaar.
- Create Tokens for transactions (Unit: 1 manhour training = 1 token)

Table 3.6: KPIs of a speciality chemical SCM

Type	**KPI**	**UOM**	**Measured by**	**Baseline 2020-2021**	**Target 2021-2022**
Lagging Indicators	Gate entry to unloading of material within same day	percent	Google sheet (post sept 21 - through System)	75	94
	Pre GRN / quality check / final GRN within 72Hours	**percent**	Through SAP report - 103 (GRN) - 105 (Quality check)	70	90
Leading Indicators	Digitization of all stores documents within 24 hours - GRN with commercial doc, Binning Report, Issue Report, Physical verification report	percent	Through SAP-DMS/ Manual Register	0	80
	No detention charges for delayed material unloading subject to vehicle entry before 4 PM	percent	Release of the truck on the same day	NA	100
	Identification of all OSD (Over/Short/Damage) and notification to supplier within 72 Hrs.	percent	Nos of consignment received vs auto notification sent	NA	100
Initiative	Tracking of returnable	percent	Monthly Gate Pass	0	95

	gate pass RGP		ageing report & circulation to user		
	Issuance of material against request within same the day subject to receive of request by 4 PM	percent	Request date vs Issuance date	85	95
Lagging Indicators	Duplicate material code cleaning	percent	Quarterly Auditing & Cleaning	NA	95
	Incorrect issuance of material	percent	No of occasions vs total nos. of issuance in a month	NA	1
	Material not available in the right bin	percent	No of occasions vs total nos. of request in a month, Bar coding	NA	1
Leading Indicators	Compliance of OEM recommended storage procedure	percent	Monthly Auditing & Compliance	NA	95
Initiative	System based Min./Max process set up for fast moving items	percent	Business process approval and system process development with training to all respective stakeholders	NA	100
	Digital Gate entry process (scanning of LWB, invoices & other docs	percent	Business process approval and system process development with training to all respective stakeholders	NA	50
	Inventory management for MOC material in SAP	percent	Business process approval and system process development with training to all respective stakeholders	NA	70
	System locking of free issue material as per drawing BOQ or approval by Project Head	percent	Business process approval and system process development with training to all respective stakeholders	NA	40
	System based shelf-	percent	Business process	NA	30

	life material management		approval and system process development with training to all respective stakeholders		
	PR validation through system- by Inventory controller	percent	Business process approval and system process development with training to all respective stakeholders	NA	100
	Auto tracking of safety/PPE items issued to contractor against approval of safety dept	percent	Business process approval and system process development with training to all respective stakeholders	NA	100
Lagging Indicators	Inventory deviation against physical verification	percent	Deviation vs Total book value	0	1
Leading Indicators	Write-off of book inventory	percent	Physical verification gap + Damage+ Expired material	NA	1
	Resource utilization (Men, Machine & Material Space)	percent	Through Physical Log sheet time study & Google sheet	NA	80
	Operation & Maintenance excess material taking into stock	percent	Through standard MRN process for taking the stock into SAP system	NA	50
	Project excess material taking into stock	percent	Through standard MRN process for taking the stock into SAP system		50
	Issuance of Engg. Spares against return of failed part	percent	Total new issued vs old returned	NA	30
	Reduction of Inventory turn around	Nos	Average Top 100 fast moving items inventory turn around calculation and action plan for reduction of one turn around (Baseline - 1)	0	-1

Lagging Indicators	Safety compliance as per Norms - Zero fatality,	percent	Safety Incident Register	1	100
	Safety compliance as per Norms - Zero fatality, Zero LTI, LTI SR <2,	percent	Safety Incident Register	1	100
	Safety compliance as per Norms - TRI (Total Recordable Incident) FR<0.2,	percent	Safety Incident Register	1	100
Lagging Indicators	Ensuring timely statutory compliance of material handling equipment, lifting gears and hired warehouse valid certification & statutory documents	percent	Calendar schedule compliance	NA	100
Initiative	Assessing the individual skill development need and setting up a calendar to trainings/workshops	percent	In collaboration with McKinsey/Academia	NA	33
	Categorisation of scrap material / waste	percent	Infrastructure and categorisation	NA	100
Lagging Indicators	Engg. Stores Scheduled Meetings/Reviews with different stakeholders	percent	Compliance to Governance calendar	NA	90
	Physical stock verification - A Category	Nos	Quarterly- Stock Verification	NA	92
	Physical stock verification - B Category	Nos	Half yearly- Stock Verification	NA	92
	Physical stock verification - C Category	Nos	Yearly - Stock Verification	NA	92

Challenges in SCM related to Planning/Process compliance (PCR)

The supply chain management worldwide is largely governed by 7R principle.

Intended material/services should reach

To Right customer/end user

At Right time

Of Right Quality

Of Right quantity

At Right place

At Right price

With Right terms & conditions

All the above cited 'rights' may proved to be ineffective in absence of right planning and process compliance. That exactly is one of the major challenges in construction SCM.

The process starts with the need validation. Unfortunately, in India, most of the projects requirements are generated without enough need validation. If the need is not validated by the business or project planning team, the need generated at different levels of project execution would either be inadequate or be over adequate.

Challenges in SCM related to Planning/Process compliance- Possible solutions through Blockchain

The construction companies suffer losses due to ineffective planning of materials and services required at different stages of project execution. If the requirements are captured in blockchain at the conceptual stage of project costing (may be during class five estimation) in sink with every activities in critical path, the supply and services can easily be monitored and controlled without unnecessarily impacting the working capital and wastages. In case of any change in specifications or delay due to any other reason, the delivery schedule, revised price, quality requirements and availabilities, order amendments and all other related activities would automatically gets modified by smart contract making it beneficial to all the stakeholders in same blockchain network.

Challenges in SCM related to Supplier/Contractor (SPR)

The biggest problem here is the over commitment without enough understanding of the consequences to somehow grab the job. Work without work order and supplies without

purchase order are very common in construction industry. Lack of resource planning, inaction in raw materials procurement, misunderstanding of the deliverables and underquoting of prices are the major factors causing delay in supplies by the suppliers or contructors. Many a times, the suppliers or contructors strategically create such situations to take advantage of the situations demanding premium price in the name of extra work or urgency or both. Missing or compromised compliance issues also play a major role for delayed or frequent change of delivery dates or inferior quality of supplies.

Challenges in SCM related to Supplier/Contractor- Possible solutions through Blockchain

Here also Smart contract can create a healthy business environment and restrain supplier/contractor from unrealistic commitment. In other words, a smart contract is a computerized digital protocol which governs, verifies, facilitates, modulates and enforces the agreed T&C of an agreement without the intervention of any intermediatory.

2014 onwards the Ethereum based smart contracts started getting momentum. Because of the transparency of Ethereum based digital technology, the smart contract gained trustworthiness. The cost benefit analysis suggests, smart contract is one of the most times & cost-effective technology going forward. Smart contract can very well bring improvements making both the parties profitable. If the purchase orders or work orders are issued through smart contracts, the system would prompt the missing or compromised activities well in advance of the failure of commitments citing the logic and initiate corrective actions & preventive actions (CAPA). Since the system will prompt failure alarm beforehand based on mutually agreed logics and nobody can change, modify or temper the data logged in smart contract blocks, the system will automatically analyse and impose penalties to the defaulters. This will expose the habitual defaulters and develop the mentality of adopting change management. Smart contract/Blockchain shall restore, trust, transparency, and traceability in construction supply chain.

The graphical representation of Blockchain based supply chain management is explained hereunder in Fig.

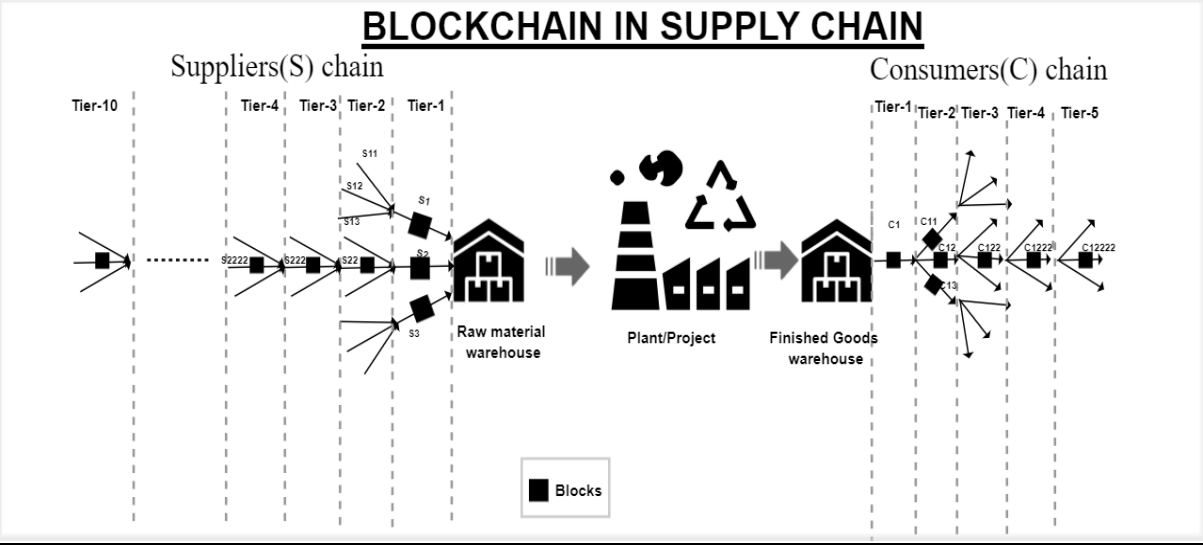


Figure 3.2: Blockchain in Supply Chain

Summary: In today's complex and competitive business world, supply chain of any organization works under tremendous pressure warranting availability of right product of right quality & right quantity from the right source at the right place at right time and right price (7R). The major challenges in supply chain management are data security, transparency, and traceability. Supply chain management is accountable for movement of materials and or services from the point of origin to the point of consumption, meaningfully connecting all the stakeholders in the complete journey. A finished goods reaches to consumers through many mediators (Tier) like whole sellers(C1), Stuckists(C12), agents(C122), retailors(C1222) etc. whereas the different raw materials required in the process come from numerous tiers of suppliers like S2-S22-S222-S2222….and so on. In case of a defect in the finished goods experienced by a consumer, the traceability of the origin of the defect becomes extremely difficult to the manufacturer or seller generating huge amount of customers dissatisfaction. Blockchain enabled supply chain can provide easy solution to this intricate problem because blockchain locks complete data/details in a block at every transaction ensuring data security, transparency, and traceability. In simple language, Blockchain is a decentralized still tamperproof data management system, which can be shared among a network of peers and each computer is known as a node.

Table 3.8: Constructs and Measurement Items for Blockchain enabled Supply Chain

S.No	Factors	Label Indicators	Measurement Items
1	Client Related	CLR	5 items • Providing leadership • Strategic alignment with end-consumer inmind • Well-articulated consumer value • Consumer Sentimental analysis • Good understanding of the system
2	Contract Management Related	CMR	6 items • Understanding the implications of theimplementation • Organizations willingness to participate inimplementation • Commitment from Department Heads • Willingness to compete in global markets • Clearly articulated governance structure • Well defined escalation mechanism
3	Supplier Related	SPR	7 items • Supply chain partners willingness tocollaborate • Establishment of long-term relationship • Commitment from supply chain partners topmanagement

			• Business Involvement of supply chain partners • Providing resources having technical expertise • Resource (information, knowledge & skills)sharing among supply chain partners • Mindset for partnership
4	Planning and Compliance Related	PCR	5 items • Pre-feasibility study of the implementation • Identifying business process rationale for thesystem • Clearly articulated governance structure • Well defined escalation mechanism • Risk Mitigation plan to be reviewed andupdated regularly
5	Unethical Practice Related	UPR	5 items • Need for open and honest communication • Commitment to change • Conflict management • Data integrity importance as sensitive information will be transferred • Secured transmission of data

3.4.2 Performance Indicators for Blockchain enabled supply chain

Table 3.9 highlights the success indicators and its measurement items.

S.No	Success Indicators	Label Indicators	Measurement Items
1	Environmental Bottom-line	ENV	4 items • Lesser waste generation • Technology adoption by supply chain partners • Digitization of all SCM documents (paperless) • Digital signing of contract documents
2	Social Bottom-line	SOB	4 items • Effectiveness of Promotions Management • Creating culture of success- Knowledge sharing among the supply chain partners • Health and Safety Compliance

			• Skillset Development planning • Employability improvement
3	Economic Bottom-line	ECB	6 items • Increased return on investment • Maximize Profit • Deliver Value to shareholders • Increased market share • Customer satisfaction • Capacity Utilization

3.5 Research Model & Basis of Hypothesis

From the literature review it has been identified that construction companies need to focus on making Blockchain enabled supply chain successful to be competitive. Literature review has suggested several studies highlighting the relationship between CSFs and implementation success and its effect firm performance (Ram, J. et al., 2013; Maditinos, D. et al., 2011; Agarwal, N. et al.,2006; Jugdev, K. et al., 2005). The model is aimed to test the effect of 'CSFs' and 'Level and extent of IT usage' on 'implementation success' along with the result of 'implementation success' on 'organisation performance'. Based on 5 factor analysis conducted in chapter 4, 24 constructs are divided in 6 'CSFs', 3 'Success Indicators' into 'Implementation success' and 3 'Performance Measures' into 'Firm Performance'. The research model along with hypothesis is depicted in figure 3.2. As 5 factors and 3 success indicators are the major contributors and neatly connected to the effective implementation of smart contracts, these have been considered as the basis of 8 hypotheses.

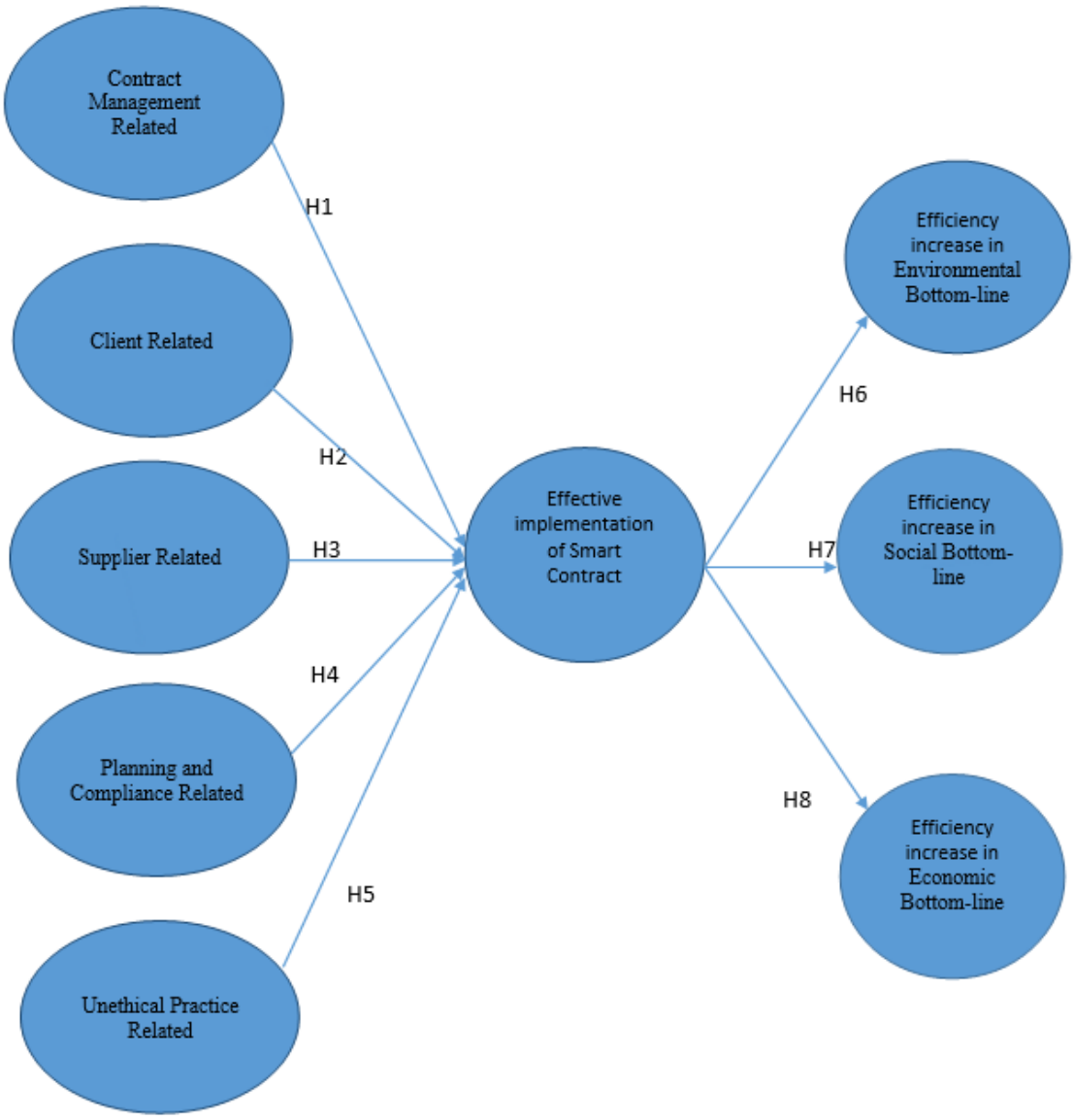


Figure 3.3: Research Model and Hypothesis

H1- Contract Management related Client related critical factors in effective implementation of smart contract (SC) in construction supply chain.

H2- Client related critical factors in effective implementation of SC in construction supply Chain.

H3- Supplier related critical factors in effective implementation of SC in construction supply chain.

H4- Planning and Compliance related critical factors in effective implementation of SC in construction supply chain.

H5- Unethical Practice related critical factors in effective implementation of SC in construction supply chain.

H6- Effect of smart contract on environmental bottom-line performance in construction supply chain.

H7- Effect of smart contract on social bottom-line performance in construction supply chain.

H8- Effect of smart contract on economic bottom-line performance in construction supply chain

The following null hypothesis are tested.

- Hypothesis 1 (H1)- "Contract Management/Governance related" (CMR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain.
- Hypothesis 2 (H2)- "Client Related" (CLR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain.
- Hypothesis 3 (H3)- "Supplier Related" (SPR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain.
- Hypothesis 4 (H4)- "Planning and Compliance Related" (PCR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain.

- Hypothesis 5 (H5)- “Unethical Practice Related” (UPR) critical factor will not affect the effective “implementation” (IS) of SC in construction supply chain.
- Hypothesis 6 (H6)- Smart contract “implementation” (IS) does not effect on “Environmental Bottom-line” (ENB) performance in construction supply chain.
- Hypothesis 7 (H7)- Smart contract “implementation” (IS) does not effect on “Social Bottom-line” (SOB) performance in construction supply chain.
- Hypothesis 8 (H8)- Smart contract “implementation” (IS) does not effect on “Economic Bottom-line” (ECB) performance in construction supply chain.

3.6 Questionnaire Design

Based on the finalization of constructs and measurement items, a structured questionnaire is designed to test the research objectives. The questionnaire is divided into three sections

- Part 1- Personal & Company Information including ‘Level and extent of Blochchain usage’: This section aims to capture questions pertaining to nature of business, current level of Blochchain usage and number of years of Blochchain usage of construction organization. Along with this it captures information pertaining to the department in which respondent is working for. In total this section has 14 questions
- Part 2 – This section has questions pertaining to Critical success factors covering all measurement items. In total this section has 28 questions

- Part 3- This section has questions pertaining to success indicators covering allmeasurement items. In total this section has 17 questions

  It has three types of questions

- Open ended questions – respondents are asked to answer questions without anyrestriction in thought process
- Five-point Likert scale – questions are asked on a scale of 1 to 5, where1 being the lowest and 5 being the highest
- Multiple choice questions – questions are asked with options provided to the respondent,with an option to select multiple responses

3.7 Pilot Study

The questionnaire is first tested for content validity and then shared with 3 academicians with relevant proficiency in digital supply chain- blockchain and 25 Industry expert in construction industry. Based on the feedback received from them, 8 questions are refined and 2 are dropped. The final questionnaireis then prepared and is attached in Annexure I.

3.8 Sample Identification

The sample of 326 executives working in Indian construction companies across India are selected from the vendor data base of a major specialty chemical and EPC (Engineering, Procurement. Construction) company.

3.9 Survey and Data Validation

Based on the sample size of 326, firstly the Linkedin profile and contact details of all 326 respondents is validated. Once confirmed that they are working for construction companies in India, interaction is initiated with all these 326 respondents. Out of 326 respondents, 190 agreed to participate in the survey but only 115 respondents provided the response. The responses receivedare glanced for the completeness and out of 115 responses, all 115 have been retained. There was not a single incomplete response.

The responses are classified by following parameters

1. Nature of the industry of the respondent

Table 3.10: Classification by the nature of the industry of the respondent

Nature of the Industry	**Count**
Manufacturing	83
Contractor	23
Consultant	9
Grand Total	**115**

2. Department of the respondent

Table 3.11: Classification by the department of the respondent

Department	**Count**
Manager	29
Officer	43
Promoter	13
General Manager	15
Top Management	15
Grand Total	**115**

3. Designation of the respondent

Table 3.12: Classification by the designation of the respondent

Designation	Count
Manager	29
Officer	43
Promoter	13
General Manager	15
Top Management	15
Grand Total	**115**

4. Type of the industry of the respondent

Table 3.13: Classification by type of the industry of the respondent

Type of the Industry	Count
Construction (Project)	67
Engineering	37
Oil & Gas	1
Chemical	1
Consultancy	9
Grand Total	**115**

5. MSME/Large/MNC

Table 3.14: Classification by MSME/Large/MNC

MSME/Large/MNC	Count
Construction (Project)	67
Engineering	37
Oil & Gas	1
Chemical	1
Consultancy	9
Grand Total	**115**

6. Age group of the respondent

Table 3.15: Classification by Age group of the respondent

Age Group	Count
<30	34
30 to 40	32
40 to 50	38
> 50	11
Grand Total	**115**

7. Geographical region of the respondent

Table 3.16: Classification by geographical region of the responden

Age Group	Count
North	24
East	12
West	64
South	15
Grand Total	**115**

3.10 Conclusion

This chapter highlights the need for the study along with mapping research objectives and gaps identified from literature review. 'Critical success factors' and 'Performance Indicators' along with the measurement items have been identified based on literature review and focus group discussion. This is then used to formulate research model along with the hypothesis and questionnaire design. Finally, sample is selected and survey is conducted. The next chapter focuses on the data analysis.

Chapter 4

DATA ANALYSIS

The chapter starts with the analysis of the respondents' profile along with the validation and reliability of the data collected. This is followed by factor analysis to consolidate the variables having similar relationship. Thereafter, focus group discussion is used to validate the grouping, followed by Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM).

4.1 Reliability

Cronbach's coefficient (α) is used to test the internal consistency and reliability of the responses. α value greater than 0.70 is considered to be good scale of reliability (Cronbach, L.J., 1951). This test is applied to 115 responses received and the value of α is 0.965. This value is greater than the desirable value, and the results suggest that responses are internally consistent and reliable.

4.2 Multivariate Analysis

Multivariate analysis via Mahalanobis distance is used for detecting outliers in the response by considering varied scales among variables and correlations between them. SPSS is used to calculate 'Mahalobnis distance'. From the results, it is clear that Mahalobnis distance is between 3.746 and 113.008. We are interested in finding the outlier and the same is calculated by 'computing the squared Mahalobnis distance between each point and the mean of the set in the original variable space and comparing it to the tabulated chi^2 distribution with (p-1) degrees of freedom' (Maesschalck, D.R. et al., 2000). Since, here data is collected by defined range 5-point Likert scale thus there are no outliers.

4.3 Exploratory Factor Analysis (EFA)

EFA is done to identify the underlying relationship between constructs. Factor analysis

describesvariability between observed, correlated variables in terms of a potentially lesser number of factors (also known as unobserved variables). Principal component analysis(PCA) extraction method is used for this study. Factor analysis has been done for CSFs, performance indicators and measures.

4.3.1 Exploratory Factor Analysis for Critical Success Factors

EFA is done with PCA as the extraction method and Varimax as the rotation method. In case there are items with cross-loading values less than 0.4 (Chin, W.W., 1998), then those items need to be deleted. In our analysis none of the cross-loading values is greater than 0.4, as indicated in table 4.1, It suggests that it doesn't need to delete any items and that it does not violate discriminant validity.

Table 4.1: Pattern matrix representing cross loading.

	Component				
	1	2	3	4	5
CMR2	.845				
CMR4	.844				
CMR3	.842				
CMR1	.605				
CLR1		.750			
CLR4		.715			
CLR5		.692			
CLR2		.691			
CLR8		.571			
CLR7		.564			
CLR6		.445			
CLR3		.443			
SPR1			.813		
SPR2			.806		
SPR3			.782		
SPR4			.619		
SPR5			.772		
SPR6			.531		
PCR3				.811	
PCR4				.795	
PCR1				.710	
PCR2				.708	
PCR6				.541	
PCR5				.524	
UPR1					.812
UPR2					.799
UPR4					.787
UPR3					.626

Kaiser-Meyer-Olkin (KMO) value measures “the correctness of number of observed values with respect to the number of variables’ (Yoon, S. et al., 2016). KMO values of greater than 0.7 is acceptable (Kim, J. et al., 1978). The result in table depicts KMO and Bartlett’s test results,KMO is 0.882 and is statistically significant.

Table 4.2: KMO & Bartlett's Test

Kaiser-Meyer-Olkin Measure for Sampling Adequacy.		0.882
Bartlett's Test of Sphericity	Approx. Chi-Square	6094.974
	Degrees of Freedom (df)	378
	Sig.	.000

All five factors accounted for 80.4 percent of variation in 28 variables, and existing literature suggests anything greater than 50 percent is acceptable (Gerbing, D.W. et al., 1987). Also, in this the eigenvalue is greater than 1 for all 5 factors supporting one-dimensionality of constructs (Kaiser, F.H., 1960). The final pattern matrix shows how the 28 variables load onto 5 factors. Cronbach's coefficient (α) is used to examine the reliability and the value of α is 0.965 post factor analysis. Thus, the results show that post factor analysis also the data is reliable. Table depicts how 28 variables load onto 5 factors along with factor loading, Eigen value, percentage of variance and Cronbach's α.

Table 4.3: Constructs EFA- pattern matrix, total variance explained & reliability.

Factors	Variables	Loading from Pattern Matrix	Eigen Value	percent of Variance	Cumulative percent	Cronbach's α
CMR	CMR1	0.605	16.879	60.281	60.281	0.945
	CMR2	0.845				
	CMR3	0.842				
	CMR4	0.844				
CLR	CLR1	0.750	2.001	7.144	67.425	0.943
	CLR2	0.691				
	CLR3	0.443				
	CLR4	0.715				
	CLR5	0.692				
	CLR6	0.445				
	CLR7	0.564				
	CLR8	0.571				
SPR	SPR1	0.813	1.499	5.352	72.777	0.886
	SPR2	0.806				
	SPR3	0.782				
	SPR4	0.619				
	SPR5	0.772				
	SPR6	0.531				
PCR	PCR1	0.710	1.113	3.974	76.752	0.924
	PCR2	0.708				
	PCR3	0.811				
	PCR4	0.795				
	PCR5	0.524				
	PCR6	0.541				
UPR	UPR1	0.812	1.023	3.653	80.405	0.950
	UPR2	0.799				
	UPR3	0.626				
	UPR4	0.787				

4.3.2 EFA for Performance Indicators

Factor analysis done for success indicators suggest that 17 variables load onto 3 factors. KMO is coming to 0.899 and is statistically significant as values greater than 0.7 is acceptable (Kim, J. et al., 1978) and is depicted in table 4.4

Table 4.4: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.899
Bartlett's Test of Sphericity	Approx. Chi-Square	1367.391
	Df	136
	Sig.	.000

Table 4.5: Pattern matrix representing cross loading.

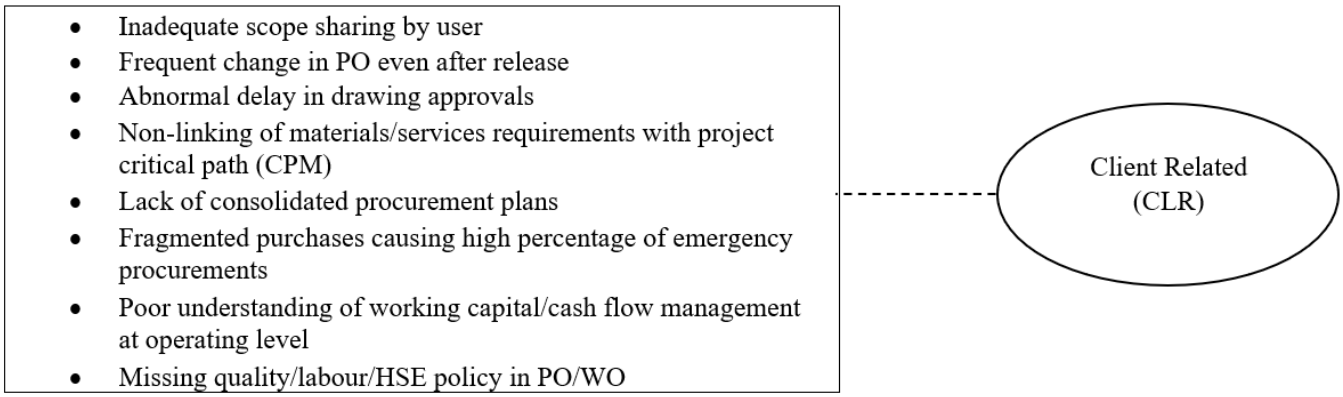
	Component		
	1	2	3
ENB1	0.844		
ENB2	0.707		
ENB3	0.695		
ENB4	0.691		
ENB5	0.642		
ENB6	0.596		
ENB7	0.518		
SOB1		0.912	
SOB2		0.907	
SOB3		0.753	
SOB4		0.571	
SOB5		0.477	
ECB1			0.816
ECB2			0.629
ECB3			0.623
ECB4			0.553
ECB5			0.502

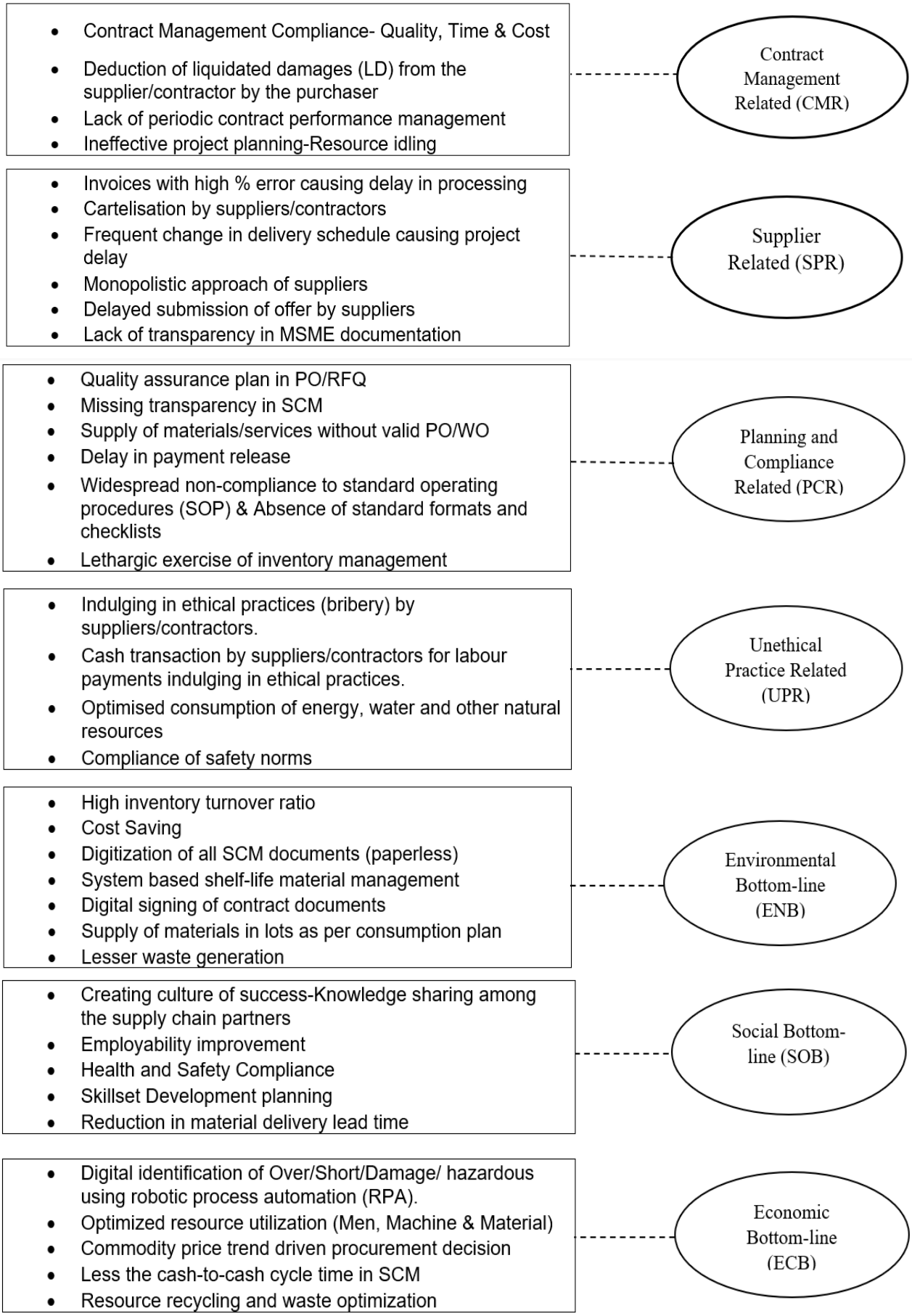
Table 4.6: Constructs post EFA- pattern matrix, total variance explained & reliability.

Factors	Variables	Loading from Pattern Matrix	Eigen Value	percent of Variance	Cumulative percent	Cronbach's α
ENB	ENB1	0.844	8.202	48.249	48.249	0.875
	ENB2	0.707				
	ENB3	0.695				
	ENB4	0.691				
	ENB5	0.642				
	ENB6	0.596				
	ENB7	0.518				
SOB	SOB1	0.912	1.638	9.634	57.883	0.885
	SOB2	0.907				
	SOB3	0.753				
	SOB4	0.571				
	SOB5	0.477				
ECB	ECB1	0.816	1.123	6.607	64.49	0.812
	ECB2	0.629				
	ECB3	0.623				
	ECB4	0.553				
	ECB5	0.502				

4.4 Factors Post EFA

Based on this, 28 variables have been divided into 5 factors, 17 variables into 3 factors. Figure depicts how these are divided into 8 factors.




Contract Management Compliance- Quality, Time & Cost
Deduction of liquidated damages (LD) from the supplier/contractor by the purchaser
Lack of periodic contract performance management
Ineffective project planning-Resource idling
Contract Management Related (CMR)
Invoices with high % error causing delay in processing
Cartelisation by suppliers/contractors
Frequent change in delivery schedule causing project delay
Monopolistic approach of suppliers
Delayed submission of offer by suppliers
Lack of transparency in MSME documentation
Supplier Related (SPR)
Quality assurance plan in PO/RFQ
Missing transparency in SCM
Supply of materials/services without valid PO/WO
Delay in payment release
Widespread non-compliance to standard operating procedures (SOP) & Absence of standard formats and checklists
Lethargic exercise of inventory management
Planning and Compliance Related (PCR)
Indulging in ethical practices (bribery) by suppliers/contractors.
Cash transaction by suppliers/contractors for labour payments indulging in ethical practices.
Optimised consumption of energy, water and other natural resources
Compliance of safety norms
Unethical Practice Related (UPR)
High inventory turnover ratio
Cost Saving
Digitization of all SCM documents (paperless)
System based shelf-life material management
Digital signing of contract documents
Supply of materials in lots as per consumption plan
Lesser waste generation
Environmental Bottom-line (ENB)
Creating culture of success-Knowledge sharing among the supply chain partners
Employability improvement
Health and Safety Compliance
Skillset Development planning
Reduction in material delivery lead time
Social Bottom-line (SOB)
Digital identification of Over/Short/Damage/ hazardous using robotic process automation (RPA).
Optimized resource utilization (Men, Machine & Material)
Commodity price trend driven procurement decision
Less the cash-to-cash cycle time in SCM
Resource recycling and waste optimization
Economic Bottom-line (ECB)

4.5 Measurement Model

Confirmatory Factor Analysis (CFA) is represented by the measurement model and is used to validate the factor analysis conducted earlier. The initial measurement model is prepared using AMOS 23.0 and the same is described in figure.

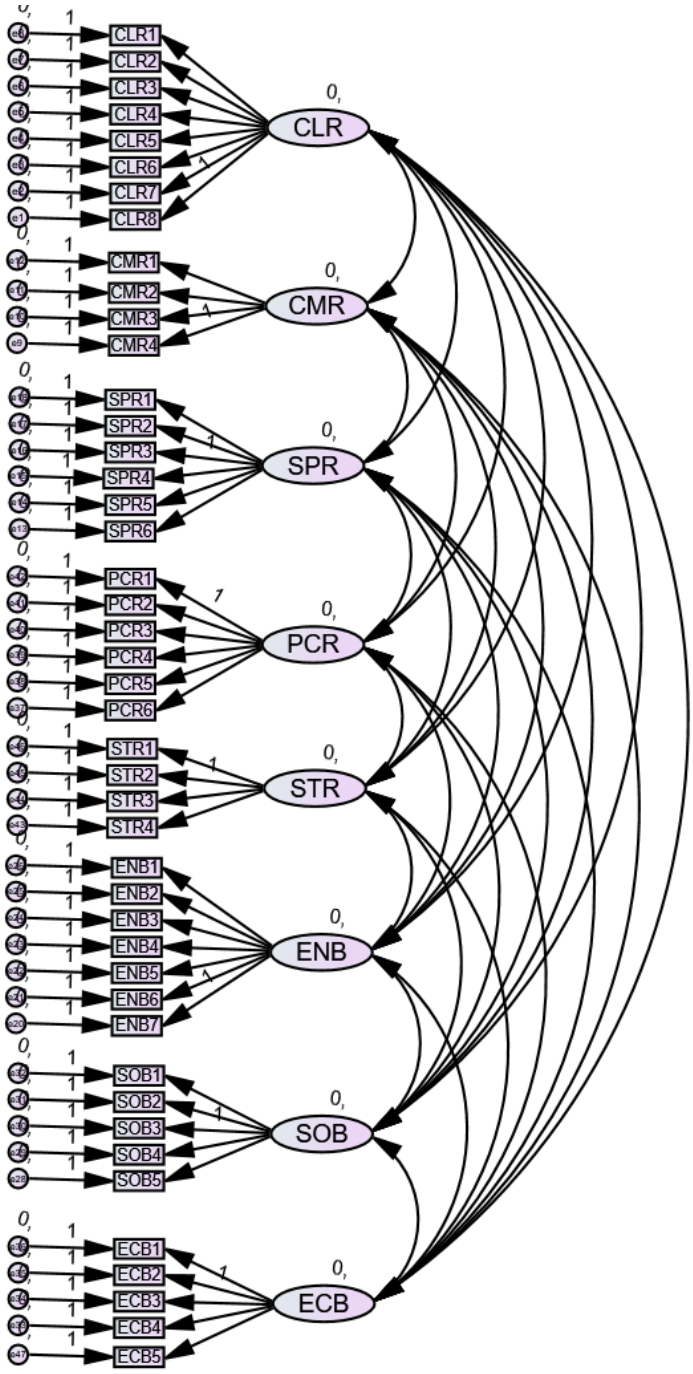


Figure 4.1: Initial Measurement Mode

Based on modifications done, the model is revised and the same is validated.

4.5.2 Validation of the Measurement Model

Model is validated by discriminant validity (each variable is distinct from others), composite reliability (measures internal consistency of indicators within a construct), convergent validity (each measured item correlates strongly with its assumed theoretical construct) and content validity (measures that is intended to) (Bo, X. et al., 2015).

Convergent validity is tested by Average variance extracted (AVE) and a minimum of 0.50 is recommended appropriate and discriminant validity is measured by using the following- 'AVE for one construct should be higher in comparison to the highest squared correlations of each variable' (Hair Jr, J. F., et al., 2014). The composite reliability(CR) value of greater than 0.7 is recommended (Bagozzi, R.P. et al., 1988). The test shows that there are 'No validity concerns' and the same is depicted below in Table 4.7.

Table 4.7: Measurement Model-Average variance extracted(AVE), composite reliability (CR)

Model Validity Measures

	CR	AVE	MSV	MaxR(H)	CLR	CMR	SPR	ENB	SOB	ECB	PCR	STR
CLR	0.986	0.972	0.362	1.005	**0.986**							0.601***
CMR	0.992	0.977	0.409	1.000	0.470***	**0.988**						0.584***
SPR	0.917	0.696	0.409	1.001	0.526***	0.640***	**0.834**					0.572***
ENB	0.867	0.521	0.510	0.870	0.281**	0.161	0.224*	**0.721**				0.217*
SOB	0.909	0.721	0.436	0.997	0.256*	0.046	0.044	0.534***	**0.849**			0.088
ECB	0.782	0.545	0.510	0.785	0.446***	0.221*	0.387***	0.714***	0.660***	**0.738**		0.326**
PCR	0.902	0.617	0.446	0.999	0.602***	0.505***	0.598***	0.244*	0.155	0.374**	**0.785**	0.668***
STR	0.956	0.847	0.446	0.996								**0.920**

4.5.3 Model Fit of the Measurement Model

To evaluate the fitness of the model, Goodness for Fit Indices (GFI) is used. GFI consistsof absolute, relative and parsimonious fits. The same is depicted below in table 4.8.

Table 4.8: Model Fit (Measurement Model)

Interpretation	**Parameter**
Absolute Fit model	$\chi 2$ / Degrees of Freedom (DF)
	Root means square error of approximation (RMSEA)
Relative fit model	Tucker–Lewis index (TLI)
	Comparative fit index (CFI)
Parsimonious fit model	Parsimonious normed-fit index(PNFI)
	Parsimonious comparative fit index(PCFI)

The recommended value of $\chi 2$ /DF is greater than 1.0 (Byrne, B.M., 1989) and RMSEA is less than 0.08 (Browne, M.W. et al., 1993). The value of $\chi 2$ /DF is 1.681 and RMSEA is 0.077, and thus the model is 'Absolute Fit'. The recommended value of TLI and CFI is more than 0.9 (Hu, L. et al., 1999). The value of TLI is 0.934 and CFI is 0.942, and the model is 'Relative Fit'. The recommended value of PNFI and PCFI is more than 0.5 (Hu, L. et al.,1999). The value of PNFI is 0.764 and PCFI is 0.828, and the model is 'Parsimonious fit'. Table depicts the threshold and actual value of each parameter.

Table 4.9: Model Fit- Threshold and Actual Value

Parameter	**Threshold Value**	**Actual Value**
$\chi 2$ / Degrees of Freedom (DF)	>1	1.681
Root mean square error of approximation (RMSEA)	<.08	0.077
Tucker–Lewis Index (TLI)	>0.9	0.934
Comparative Fit Index (CFI)	>0.9	0.942
Parsimonious normed-fit index (PNFI)	>0.5	0.764
Parsimonious Comparative Fit Index (PCFI)	>0.5	0.828

4.5.4 Estimates and Correlations

The results of estimates are in line with the grouping done via factor analysis and are statistically significant. The standardized factor loadings of construct items are depicted in table 4.10, with all values being statistically significant at 99 percent confidence level.

Table 4.10: Standardized Factor Loading

Factors	Variable	Factor Loading
Client Related (CLR)	CLR1	1.00
	CLR4	0.97
Contract Management Related (CMR)	CMR2	1.00
	CMR3	1.00
	CMR4	0.97
Supplier Related (SPR)	SPR1	0.77
	SPR2	0.75
	SPR3	1.00
	SPR5	0.99
	SPR6	0.60
Planning and Compliance Related (PCR)	PCR1	1.00
	PCR2	0.98
	PCR3	0.71
	PCR4	0.68
	PCR5	0.59
	PCR6	0.64
Unethical Practice Related (UPR)	UPR1	0.99
	UPR2	1.00
	UPR3	0.73
	UPR4	0.94
Environmental Bottom-line (ENB)	ENB2	0.66
	ENB3	0.74
	ENB4	0.75
	ENB5	0.77
	ENB6	0.67
	ENB7	0.73
Social Bottom-line (SOB)	SOB1	0.98
	SOB2	0.65
	SOB3	0.71
	SOB4	1.00
Economic Bottom-line (ECB)	ECB1	0.69
	ECB2	0.74
	ECB3	0.76

Correlation is used to find the relationship between the 8 factors. From the results obtained, a strong correlation exists between them and all correlations are depicted in table 4.11.

Table 4.11: Correlations

Correlation			Estimate
CLR	<-->	SPR	.526
CLR	<-->	ENB	.281
CLR	<-->	SOB	.256
CLR	<-->	ECB	.446
CLR	<-->	PCR	.602
CMR	<-->	SPR	.640
CMR	<-->	ENB	.161
CMR	<-->	SOB	.046
CMR	<-->	ECB	.221
CMR	<-->	PCR	.505
UPR	<-->	CMR	.584
SPR	<-->	ENB	.224
SPR	<-->	SOB	.044
SPR	<-->	ECB	.387
UPR	<-->	SPR	.572
ENB	<-->	SOB	.534
ENB	<-->	ECB	.714
ENB	<-->	PCR	.244
UPR	<-->	ENB	.217
SOB	<-->	ECB	.660
SOB	<-->	PCR	.155
UPR	<-->	SOB	.088
UPR	<-->	PCR	.668
CLR	<-->	CMR	.470
SPR	<-->	PCR	.598
UPR	<-->	ECB	.326
ECB	<-->	PCR	.374
UPR	<-->	CLR	.601

4.6 Final Measurement Model

The final measurement model which successfully passes validation and model fit is depicted in figure 4.2

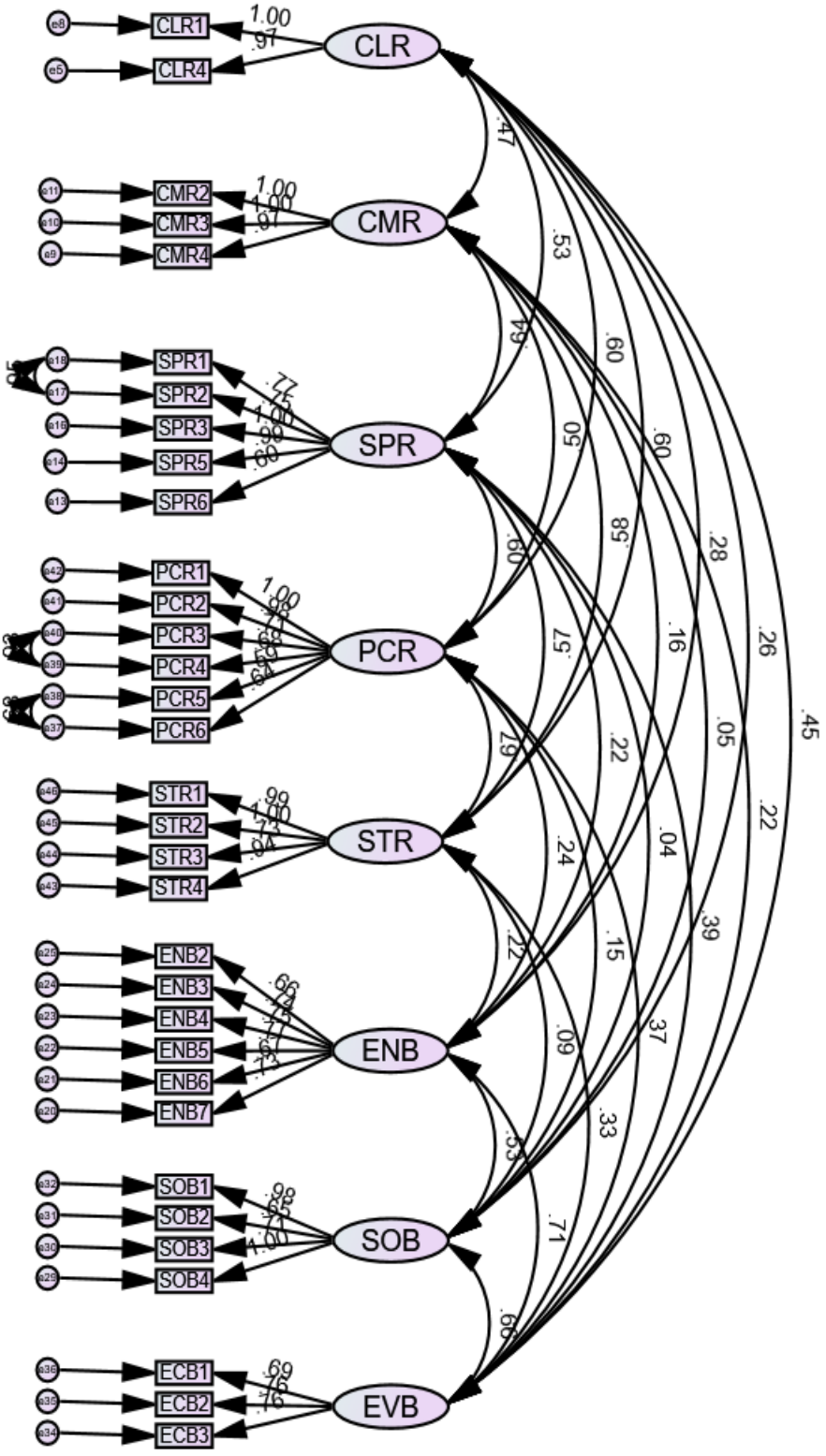


Figure 4.2: Final Measurement Model.

4.7 Structural Model

After the measurement model, the same is converted into the structural model basis research model. The research model that is being tested with structural model is illustrated in figure 4.3

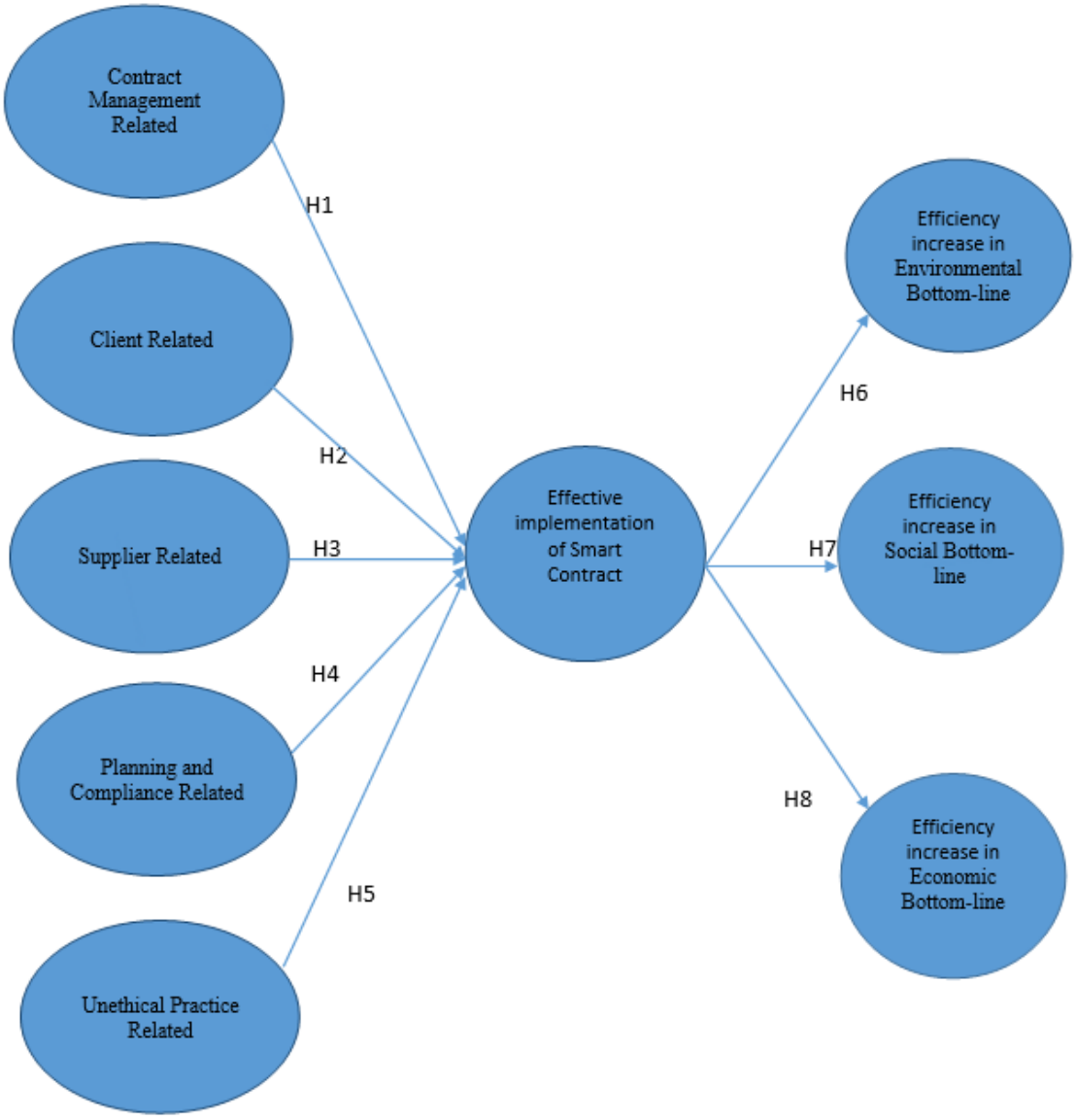


Figure 4.3: Research Model to be tested with SEM

The structural model is used to estimate the strengths among the latent constructs of the hypothesized relationships. Firstly, the condition of multi-collinearity and sample size is checkedbefore proceeding with Structural Equation Modeling (SEM).

4.8 Collinearity

Multi-collinearity is due to "ill conditioning" of data (Jagpal, S.H., 1982). The two widely used measures for degree of multi-collinearity are tolerance and Variance Inflation Factor (VIF) (O'brien, R.M., 2007). Recommended value of VIF is less than 10 (O'brien, R.M., 2007) and cause of concern is tolerance less than 0.20 (Menard, S., 1995). In table, values of tolerance are all more than 0.2 and values of VIF are less than 10, thus no multi-collinearity exists.

4.9 Minimum Sample Size Calculation

Minimum sample size is driven by 'rule of thumb' which specifies that the minimum required sample size should be as much as '10 times the largest number of constructs for any dependent variable' (Barclay, D. et al., 1995). In our case the largest number of constructs for a dependent variable is 8 and thus anything greater than 80 is adequate. Another theory suggests that sample size needs to be between 100 and 200 for SEM (Bagozzi, R.P. et al., 1988). Thus, our sample size of 115 is adequate.

4.9.1 Initial Structural Model

Initial structural model is prepared and is described in figure 4.4

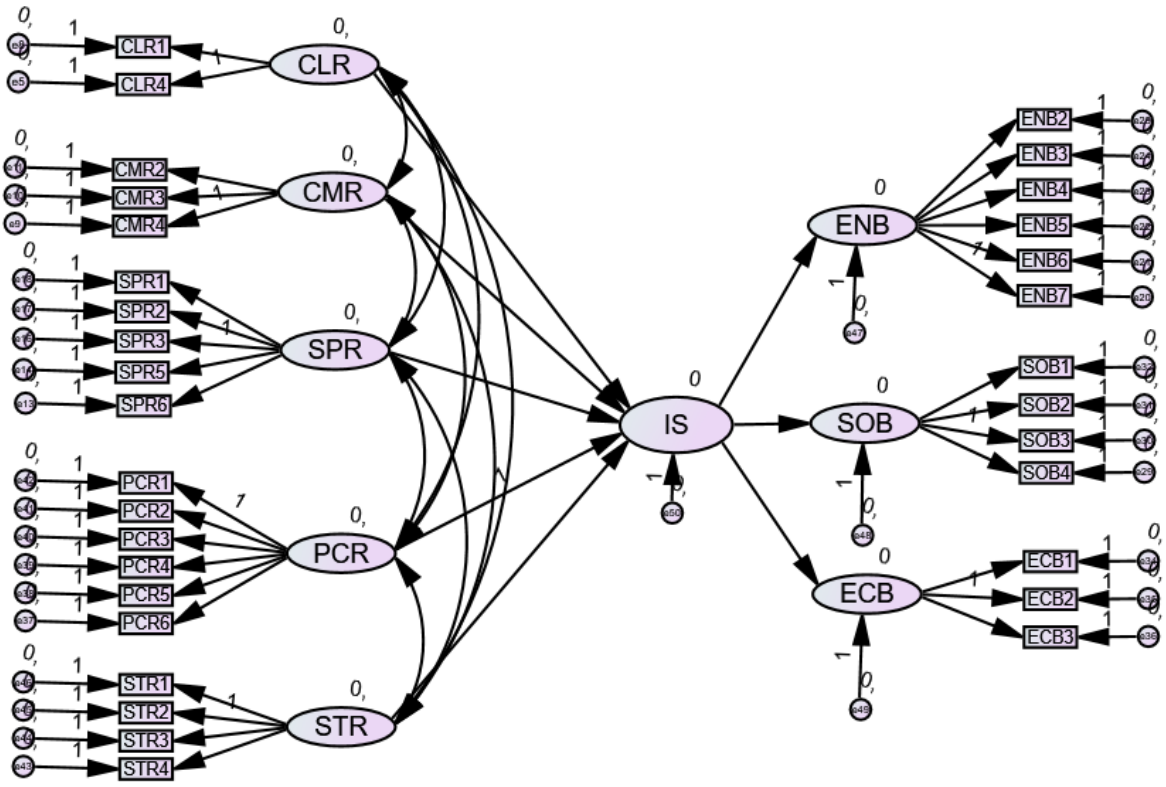


Figure 4.4: Initial Structural Model

Based on the modifications done, the model is revised and the same is validated using model of fit parameters.

4.9.2 Model fit of the Structural Model

Goodness for Fit Indices (GFI) is used to evaluate the fitness of structural model. GFI parametersare the same, as used in the section.

The recommended value of $\chi 2$ /DF is greater than 1.0 (Byrne, B.M., 1989) and RMSEA is less than 0.08 (Browne, M.W. et al., 1993). The value of $\chi 2$ /DF is 1.670 and RMSEA is 0.077, and thus the model is 'Absolute Fit'. The recommended value of TLI and CFI is more than 0.9 (Hu,

L. et al., 1999). The value of TLI is 0.935 and CFI is 0.941, and the model is 'Relative Fit'. The recommended value of PNFI and PCFI is more than 0.5 (Hu, L. et al.,1999). The value of PNFI is 0.778 and PCFI is 0.845, and the model is 'Parsimonious fit'. Table depicts the threshold and actual value of each parameter.

Table 4.12: Model Fit (Structural Model)

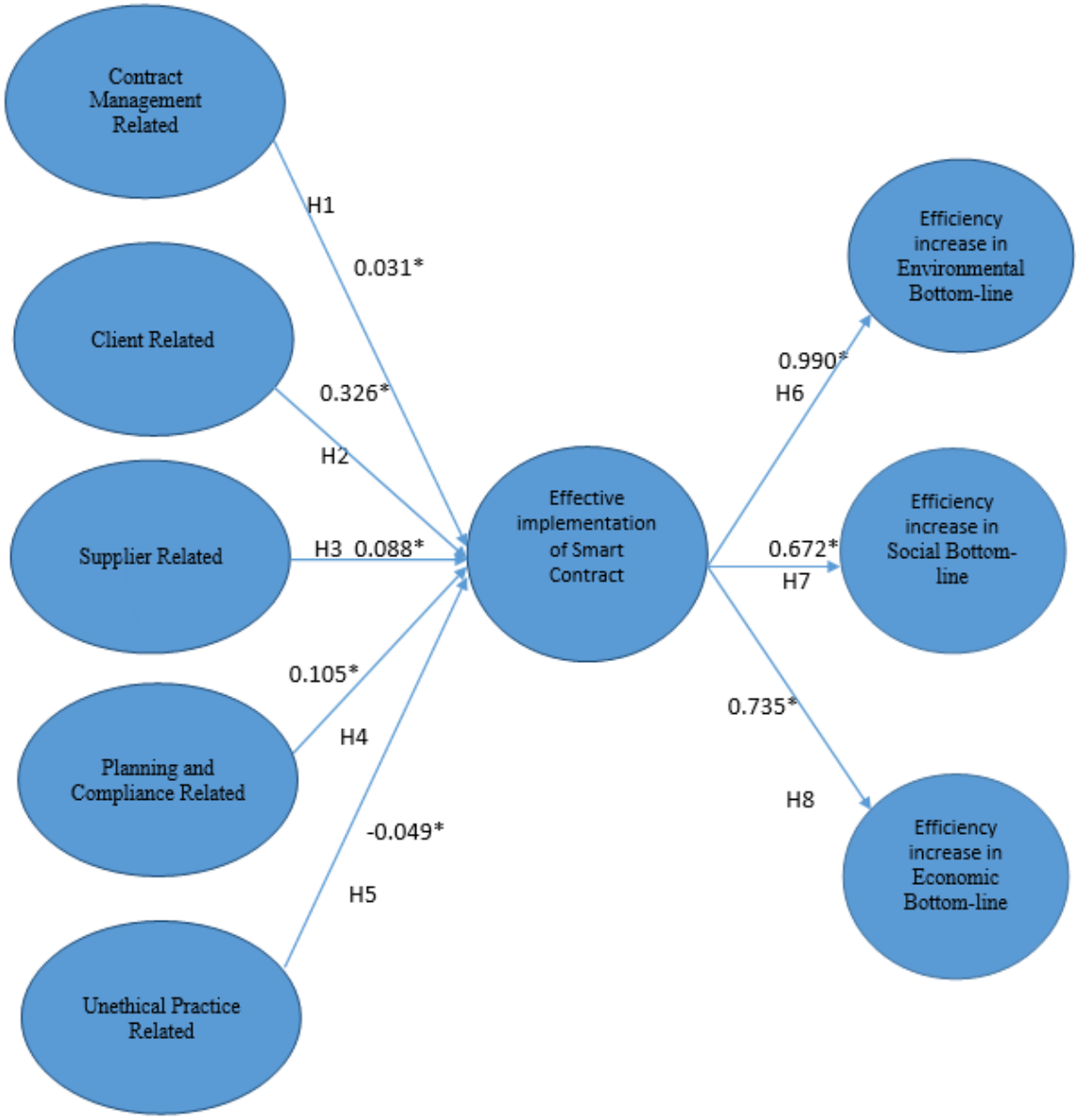
Parameter	**Threshold**	**Actual Value**
$\chi 2$ / Degrees of Freedom (DF)	>1	1.670
Root mean square error of approximation	<.08	0.077
Tucker–Lewis Index (TLI)	>0.9	0.935
Comparative Fit Index (CFI)	>0.9	0.941
Parsimonious normed-fit index (PNFI)	>0.5	0.778
Parsimonious Comparative Fit Index (PCFI)	>0.5	0.845

4.9.3 Structural Relationships: Estimates and Correlations

Table 4.13: Structural Equation Modeming Results (Regression Weights)

			Estimate
IS	<---	PCR	.105
IS	<---	UPR	-.049
IS	<---	SPR	.088
IS	<---	CMR	.031
IS	<---	CLR	.326
ECB	<---	IS	.990
SOB	<---	IS	.672
ENB	<---	IS	.735

Correlation between exogenous variables is depicted in table 4.16. It highlights the strong positive correlation between factors.



*99 percent significance level

Figure 4.5: Structural Model Estimates

Table 4.14: Correlation between Exogenous Variables

Correlation			Estimate
CLR	<-->	SPR	.529
CLR	<-->	PCR	.604
CMR	<-->	SPR	.640
CMR	<-->	PCR	.505
UPR	<-->	CMR	.584
UPR	<-->	SPR	.571
UPR	<-->	PCR	.668
CLR	<-->	CMR	.474
SPR	<-->	PCR	.597
UPR	<-->	CLR	.602

4.10 Final Structural Model

Final structural model which is fit as depicted in figure 4.6

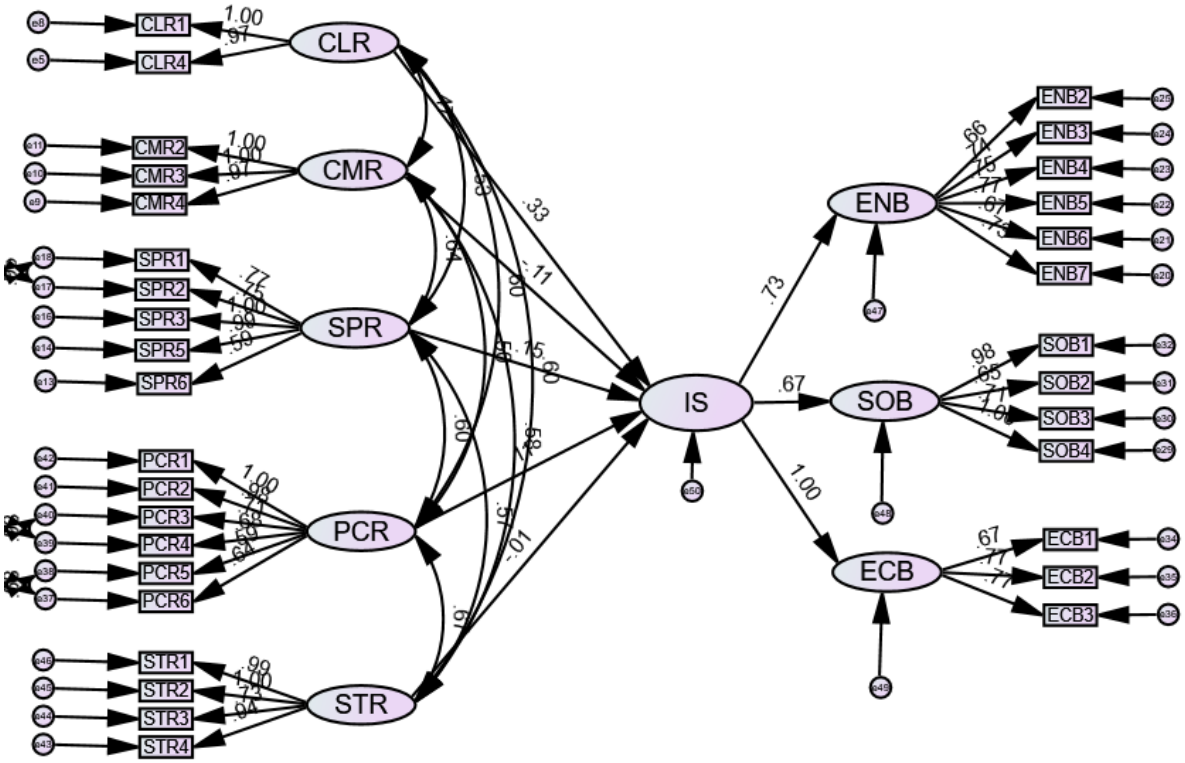


Figure 4.6: Final Structural Model

From the table, it can be depicted that the Chi-Square result is significant at 99 percent significance level and thus it can be interpreted that Critical Success Factors, Environmental Bottom-line, Social Bottom-line and Economic Bottom-line have association with "Implementation Success".

Table 4.15: Critical Success Factors, Environmental Bottom-line, Social Bottom-line and Economic Bottom-line have association with "Implementation Success".

	Value
Chi-Square	791.707
Degrees of freedom	474
Probability level	.000

The test suggests that Critical Success Factors, Environmental Bottom-line, Social Bottom-line and Economic Bottom-line have significant association (99 percent significant level) with successful implementation.

4.11 Conclusion

The chapter has analysed the collected data and has presented the respondents' profile summary. Based on the EFA, total eight factors have been extracted and the same is validated via CFA. It further analyses the effect of five CSFs on implementation of Blockchain Technology in Construction Supply Chain Management using SEM. It further analyses the effect of Critical Success Factors, Environmental Bottom-line, Social Bottom-line and Economic Bottom-line in the organization on implementation of Blockchain Technology in Construction Supply Chain Management using Chi-Square test. Finally, the direct effect of successful implementation (IS) of Blockchain Technology enabled supply chain on Environmental Bottom-line, Social Bottom-line and Economic Bottom-line along with indirect effect is analysed.

Thus, hypotheses have been tested by using SEM and Chi-Square. The next chapter focuses on interpretation of results.

Chapter 5

RESULTS AND DISCUSSION

The chapter aims to interpret the results which have been achieved by statistical tests conducted in chapter 4. All 8 hypotheses have been statistically tested using SEM and Chi-Square and have been explained along with the results achieved. Chi-Square is used to test the association between Critical Success Factors, Environmental Bottom-line, Social Bottom-line & Economic Bottom-line on "Implementation Success". SEM is used to test the effect of five CSFs on implementation of Blockchain Technology in Construction Supply Chain Management along with the effect of implementation on Environmental Bottom-line, Social Bottom-line & Economic Bottom-line along with indirect effect is analysed. In subsequent sections, all 8 hypotheses along with the results achieved have been described.

5.1 Hypothesis H1

"Contract Management/Governance related" (CMR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain.

Based on the factor analysis conducted "Contract Management/Governance related" (CMR) CSF consists of the following constructs- "Contract Management Compliance- Quality, Time & Cost" (CMR1), "Deduction of liquidated damages (LD) from the supplier/contractor by the purchaser" (CMR2), "Lack of periodic contract performance management" (CMR3) and "Ineffective Project Planning-Resource idling" (CMR4). The result is validated via CFA, and it shows the standardized loading of all constructs on "CMR" is statistically significant with factor loading on "CMR" of "CMR1" as 0.605, "CMR2" as 0.845, "CMR3" as 0.842, and "CMR4" as 0.844. This is in line with the EFA conducted.

Further SEM is conducted and the results of SEM depict that the coefficient for the path from "Contract Management/Governance related" (CMR) to "Implementation" (IS) is positive and

significant at 99 percent significant level (β =0.031, $p<0.001$). Thus, it can be interpreted that "Contract Management/Governance related" (CMR) CSF positively affects "Implementation Success" (IS).

From the above analysis, hypothesis 1 has been rejected and it can be said that "Contract Management/Governance related" (CMR) critical factor will affect the effective "implementation" (IS) of smart contract in construction supply chain.

5.2 Hypothesis H2

"Client Related" (CLR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain.

Based on the factor analysis conducted "Client Related" (CLR) CSF consists of the following constructs- "Inadequate scope sharing by user" (CLR1), "Frequent change in PO even after release" (CLR2), "Abnormal delay in drawing approvals" (CLR3), "Non-linking of materials/services requirements with project critical path (CPM)" (CLR4), "Lack of consolidated procurement plans" (CLR5), "Fragmented purchases causing high percentage of emergency procurements" (CLR6), "Poor understanding of working capital/cash flow management at operating level" (CLR7) and "Missing quality/labour/HSE policy in PO/WO" (CLR8). The result is validated via CFA, and it shows the standardized loading of all constructs on "CLR" is statistically significant with factor loading on "CLR" of "CLR1" as 0.750, "CLR2" as 0.691, "CLR3" as 0.443, "CLR4" as 0.715, "CLR5" as 0.692, "CLR6" as 0.445, "CLR7" as 0.564, and "CLR8" as 0.571. This is in line with the EFA conducted.

Further SEM is conducted and the results of SEM depict that the coefficient for the path from "Client Related" (CLR) to "Implementation" (IS) is positive and significant at 99 percent significant level (β =0.326, $p<0.001$). Thus, it can be interpreted that "Client Related" (CLR) CSF positively affects "Implementation Success" (IS).

From the above analysis, hypothesis 2 has been rejected and it can be said that "Client

Related" (CLR) critical factor will affect the effective "implementation" (IS) of smart contract in construction supply chain.

5.3 Hypothesis H3

"Supplier Related" (SPR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain.

Based on the factor analysis conducted "Supplier Related" (SPR) CSF consists of the following constructs- "Invoices with high percent error causing delay in processing" (SPR1), "Cartelization by suppliers/contractors" (SPR2), "Frequent change in delivery schedule causing project delay" (SPR3), "Monopolistic approach of suppliers" (SPR4), "Delayed submission of offer by suppliers" (SPR5), and "Lack of transparency in MSME documentation" (SPR6). The result is validated via CFA, and it shows the standardized loading of all constructs on "SPR" is statistically significant with factor loading on "SPR" of "SPR1" as 0.813, "SPR2" as 0.806, "SPR3" as 0.782, "SPR4" as 0.619, "SPR5" as 0.772, and "SPR6" as 0.531. This is in line with the EFA conducted.

Further SEM is conducted and the results of SEM depict that the coefficient for the path from "Supplier Related" (SPR) to "Implementation" (IS) is positive and significant at 99 percent significant level ($\beta = 0.088$, $p < 0.001$). Thus, it can be interpreted that "Supplier Related" (SPR) CSF positively affects "Implementation Success" (IS).

From the above analysis, hypothesis 3 has been rejected and it can be said that "Supplier Related" (SPR) critical factor will affect the effective "implementation" (IS) of smart contract in construction supply chain.

5.4 Hypothesis H4

"Planning and Compliance Related" (PCR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain.

Based on the factor analysis conducted "Planning and Compliance Related" (PCR) CSF consists of the following constructs- "Quality assurance plan in PO/RFQ" (PCR1), "Missing transparency in SCM" (PCR2), "Supply of materials/services without valid PO/WO" (PCR3), "Delay in payment release" (PCR4), "Widespread non-compliance to standard operating procedures (SOP) & Absence of standard formats and checklists" (PCR5), and "Lethargic exercise of inventory management" (PCR6). The result is validated via CFA, and it shows the standardized loading of all constructs on "PCR" is statistically significant with factor loading on "PCR" of "PCR1" as 0.710, "PCR2" as 0.708, "PCR3" as 0.811, "PCR4" as 0.795, "PCR5" as 0.524, and "PCR6" as 0.541. This is in line with the EFA conducted.

Further SEM is conducted and the results of SEM depict that the coefficient for the path from "Planning and Compliance Related" (PCR) to "Implementation" (IS) is positive and significant at 99 percent significant level(β =0.105, $p<0.001$). Thus, it can be interpreted that "Planning and Compliance Related" (PCR) CSF positively affects "Implementation Success" (IS).

From the above analysis, hypothesis 4 has been rejected and it can be said that "Planning and Compliance Related" (PCR) critical factor will affect the effective "implementation" (IS) of smart contract in construction supply chain.

5.5 Hypothesis H5

"Unethical Practice Related" (UPR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain.

Based on the factor analysis conducted "Unethical Practice Related" (UPR) CSF consists of the following constructs- "Inadequate scope sharing by user" (UPR1), "Frequent change in PO even after release" (UPR2), "Abnormal delay in drawing approvals" (UPR3), and "Non-linking of materials/services requirements with project critical path (CPM)" (UPR4). The result is validated via CFA, and it shows the standardized loading of all constructs on "UPR" is statistically significant with factor loading on "UPR" of "UPR1" as 0.812, "UPR2" as 0.799,

"UPR3" as 0.626, and "UPR4" as 0.787. This is in line with the EFA conducted.

Further SEM is conducted and the results of SEM depict that the coefficient for the path from "Unethical Practice Related" (UPR) to "Implementation" (IS) is negative and significant at 99 percent significant level (β= -0.049, $p<0.001$). Thus, it can be interpreted that "Unethical Practice Related" (UPR) CSF negatively affects "Implementation Success" (IS).

From the above analysis, hypothesis 5 has been rejected and it can be said that "Unethical Practice Related" (UPR) critical factor will affect the effective "implementation" (IS) of smart contract in construction supply chain.

5.6 Hypothesis H6

Smart contract "implementation" (IS) does not effect on "Environmental Bottom-line" (ENB) performance in construction supply chain.

Based on the factor analysis conducted "Environmental Bottom-line" (ENB) CSF consists of the following constructs- "High inventory turnover ratio" (ENB1), "Ecology saving" (ENB2), "Digitization of all SCM documents" (ENB3), "System based shelf-life material management" (ENB4), "Digital signing of contract documents" (ENB5), and "Supply of materials in lots as per consumption plan" (ENB6), and "Lesser waste generation" (ENB7). The result is validated via CFA, and it shows the standardized loading of all constructs on "ENB" is statistically significant with factor loading on "ENB" of "ENB1" as 0.844, "ENB2" as 0.707, "ENB3" as 0.695, "ENB4" as 0.691, "ENB5" as 0.642, "ENB6" as 0.596, and "ENB7" as 0.518 This is in line with the EFA conducted.

Further SEM is conducted and the results of SEM depict that the coefficient for the path from Smart contract "Implementation" (IS) to "Environmental Bottom-line" (ENB) is positive and significant at 99 percent significant level(β =0.735, $p<0.001$). Thus, it can be interpreted that Smart contract "implementation" (IS) positively affect "Environmental Bottom-line" (ENB).

From the above analysis, hypothesis 6 has been rejected and it can be said that Smart

contract “implementation” (IS) will affect “Environmental Bottom-line” (ENB).

5.7 Hypothesis H7

Effect of smart contract (IS) on “Social Bottom-line” (SCB) performance in construction supply chain.

Based on the factor analysis conducted “Social Bottom-line” (SCB) consists of the following constructs- “Creating culture of Success-Knowledge sharing among the supply chain partners” (SCB1), “Employability improvement” (SCB2), “Health and Safety Compliance” (SCB3), “Skillset Development planning” (SCB4), and “Reduction in material delivery lead time” (SCB5). The result is validated via CFA, and it shows the standardized loading of all constructs on “SCB” is statistically significant with factor loading on “SCB” of “SCB1” as 0.912, “SCB2” as 0.907, “SCB3” as 0.753, “SCB4” as 0.571, and “SCB5” as 0.477. This is in line with the EFA conducted.

Further SEM is conducted and the results of SEM depict that the coefficient for the path from “Implementation” (IS) to “Social Bottom-line” (SCB) is positive and significant at 99 percent significant level ($\beta = 0.735$, $p < 0.001$). Thus, it can be interpreted that Smart contract “implementation” (IS) will positively affect “Social Bottom-line” (SCB).

From the above analysis, hypothesis 7 has been rejected and it can be said that Smart contract “implementation” (IS) will affect “Social Bottom-line” (SCB).

5.8 Hypothesis H8

Smart contract “implementation” (IS) does not effect on “Economic Bottom-line” (ECB) performance in construction supply chain.

Based on the factor analysis conducted “Economic Bottom-line” (ECB) CSF consists of the following constructs- “Digital identification of Over/Short/Damage/ hazardous using robotic

process automation (RPA)" (ECB1), "Optimized resource utilization (Men, Machine & Material)" (ECB2), "Commodity price trend driven procurement decision" (ECB3), "Less the cash-to-cash cycle time in SCM" (ECB4), and "Resource recycling and waste optimization" (ECB5). The result is validated via CFA, and it shows the standardized loading of all constructs on "ECB" is statistically significant with factor loading on "ECB" of "ECB1" as 0.816, "ECB2" as 0.629, "ECB3" as 0.623, "ECB4" as 0.553, and "ECB5" as 0.502. This is in line with the EFA conducted.

Further SEM is conducted and the results of SEM depict that the coefficient for the path from "Implementation" (IS) to "Economic Bottom-line" (ECB) is positive and significant at 99 percent significant level ($\beta = 0.990$, $p < 0.001$). Thus, it can be interpreted that Smart contract "implementation" (IS) will positively affect "Economic Bottom-line" (ECB).

From the above analysis, hypothesis 8 has been rejected and it can be said that Smart contract "implementation" (IS) will affect "Economic Bottom-line" (ECB).

5.9 Result of Hypothesis

Based on the above analysis, the results of the 8 hypotheses are as follows

- Hypothesis 1 (H1)- "Contract Management/Governance related" (CMR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain. **(Reject)**
- Hypothesis 2 (H2)- "Client Related" (CLR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain. **(Reject)**
- Hypothesis 3 (H3)- "Supplier Related" (SPR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain. **(Reject)**
- Hypothesis 4 (H4)- "Planning and Compliance Related" (PCR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain. **(Reject)**
- Hypothesis 5 (H5)- "Unethical Practice Related" (UPR) critical factor will not affect the effective "implementation" (IS) of smart contract in construction supply chain. **(Reject)**

- Hypothesis 6 (H6)- Smart contract "implementation" (IS) does not effect on "Environmental Bottom-line" (ENB) performance in construction supply chain. **(Reject)**
- Hypothesis 7 (H7)- Effect of smart contract (IS) on "Social Bottom-line" (SCB) performance in construction supply chain. **(Reject)**
- Hypothesis 8 (H8)- Smart contract "implementation" (IS) does not effect on "Economic Bottom-line" (ECB) performance in construction supply chain. **(Reject)**

5.3 Conclusion

The results suggest that all CSFs positively impact implementation of IT-enabled Supply Chain. Also, "Level Smart contract Usage" and "Extent of Smart contract Usage" in the organization is associated with "Triple Bottom Line of business" which ensures sustainability of construction industry. Implementation of Smart contract in construction Supply Chain improves Firm Performance. The next chapter concludes the research work along with managerial implication of the research, limitations, and the future scope.

Chapter 6

CONCLUSION

This chapter emphasises the major outcomes and fulfilment of research objectives identified in chapter three. It also discusses the organisational and academic implications of the research, limitations and the future scope of research.

6.1 Main Finding of the Research

Main findings of this research are summarized below

- Twenty-eight constructs impacting implementation of Smart Contract (Blockchain) in Construction Supply Chain have been identified and grouped into five CSFs- "Client Related (CLR)", "Contract Management Related (CMR)", "Supplier Related (SPR)", "Planning and Compliance Related (PCR)" and "Unethical Practice Related (UPR)".
- Three "Performance Indicators" used to evaluate impact of Smart Contract in Construction Supply Chain are "Environmental Bottom-Line (ENV)", "Social Bottom-Line (SOB)" and "Economic Bottom-Line (ECB)". They are grouped into one factor named "Success Indicators".
- Three "Performance Indicators"- "Environmental Bottom-Line (ENV)", "Social Bottom-Line (SOB)" and "Economic Bottom-Line (ECB)" represent the three pillars of sustainability of business.

- The research has emphasized the positive impact of “Construction Sector Specific” CSF on implementation of Blockchain in Supply Chain.
- Highlights the importance of Blockchain in creating a sustainable supply chain ecosystem based on trust, transparency and traceability.
- CSFs- “Client Related (CLR)”, “Contract Management Related (CMR)”, “Supplier Related (SPR)”, “Planning and Compliance Related (PCR)” and “Unethical Practice Related (UPR)”, do not have a significant impact on implementation of Blockchain in construction Supply Chain.
- Implementation of Blockchain in construction Supply Chain is correlated with the number of years IT has been in use in the organization.
- The performance of the firm increases with implementation of Blockchain in construction Supply Chain.

6.2 Accomplishment of Research Objectives

This section summarizes how the research has been able to fulfil the objectives. Each of the objectives, along with the observations, is detailed below.

Objective 1: To identify areas where the blockchain provides the most value for construction supply chain management.

Based on the extensive literature review and virtual focused group discussion among 46 SCM professionals in construction sector, primarily identified 31 areas, further deliberated and considered top 15 areas where blockchain can provide the most value for construction supply chain

Blockchain being a decentralised digital ledger network, all the stakeholders starting from the owner/user to the supplier or contractor can be easily taken into this network primarily to establish a trustworthy business environment where every stakeholder shall be able to operate with confidence and without having any threat of losing. Once the major hurdle is taken care of by the digital technology, the other gaps can be bridged without many challenges. The stakeholders will know that whatever commitment they give to the other member in the network shall be stored in a particular block. Everyone in the network can see the commitment/data of others but cannot alter even the slightest. In case of failure of fulfilling the commitment or new promise date or change request of the earlier scope, a new set of data/commitment can be generated in a new block without any impact on the previous block. Even in case of consensus of respective stakeholders, the same protocol will be followed and the earlier block data will remain unchanged. This will bring discipline in the business environment and strengthen the sense of accountability at every level of commitment.

Objective 2: To identify drivers, barriers, and risk to blockchain deployment within construction supply chains management.

Based on the literature review and virtual focus group discussion, initially identified 22 drivers/barriers/risks to blockchain deployment. Further deliberated and considered top 10 areas to identify drivers, barriers, and risk to blockchain deployment within construction supply chains management. Risk and barrier identification leads to accountability setting. Accountability will ensure more and more transparency at every transaction level. People will be forced to avoid judgemental approach and will

be encouraged to exercise data supported decision making. When the decisions are data supported, the accuracy level will drastically improve.

Higher accuracy will trigger higher quality at every transaction level and improve the efficiency of SCM.

To maintain the data integrity in a particular business network, permissioned blockchain would be most effective. In this protocol, the stakeholders/business partners will need permission to join the blockchain network, but it will maintain a decentralised digital data management system among the participating members and create a positive ecosystem.

Objective 3: To explore the factors influencing the deployment of smart contracts (SC) as well as their success indicators in Indian construction supply chain management.

Conducted 11 sustainable SCM workshops involving 165 suppliers/contractors to understand the influencing factors in smart contract deployment. Designed a model to define the success indicators of SC in SCM. Smart contract is a self-managed agreement between two or more agencies where the terms & conditions (T&C) are codified in a trustworthy, immutable, distributed, decentralised ledger based on blockchain network.

Beauty of smart contract is, once released, even the creator or owner cannot change the any T&C contract. Each transaction is recorded and executed completely on paperless digital platform without any manual intervention, thus it is time effective and environment friendly. Transactions once done, cannot be reversed. Most importantly, the payment flows as per the agreed T&C and strengthen the trust among the engaged parties.

To explain in simple way, a smart contract is a computerised digital protocol which governs, verifies, facilitates, modulates and enforces the agreed T&C of an agreement without the intervention of any intermediatory.

2014 onwards the Ethereum based smart contracts started getting momentum.

Because of the transparency of Ethereum based digital technology, the smart contract gained trustworthiness. The cost benefit analysis suggests, smart contract is one of the most time & cost-effective technology going forward.

Objective 4: To evaluate the impact of critical factors on effective implementation of smart contracts in construction supply chain management.

The finding that implementation of Blockchain in Construction Supply Chain improves "Firm Performance" among Indian construction companies is in line with the existing literature. One more finding of this research is that "Organizational", "Inter-Organizational" and "Human" CSFs have statistically significant indirect effect on firm performance. It can be concluded that organisation performance is improved by implementation of Blockchain in Supply Chain among Indian construction companies.

Objective 5: To evaluate the effect of smart contracts on performance of the construction supply chain management.

Based on the identified KPIs of construction/project SCM and identified factors, designed

a structured questionnaire in consultation with my supervisor and industry experts.

Sent the questionnaire to 3 academicians & 25 industry experts for validation.

6.3 Implications of the Research

This research will help organisations (managers) and academicians working in construction sector to prepare well for implementing Blockchain in Supply Chain efficiently and effectively. Some implications of this research are mentioned below.

6.3.1 Organisational Implications

- Helps managers to focus on important CSFs influencing Blockchain implementation in Supply Chain
- Improves decision making by strengthening the fact that firm performance is

positively influenced by implementation of Blockchain in Supply Chain. This helps managers in making the organization competitive and improving market positioning.

- Managers should understand that implementing Blockchain in Supply Chain provides a lot of advantages to the organization and hence should be an area of focus
- Managers should focus on both type of CSFs for Blockchain implementation- Soft CSFs like "Client Related (CLR)", "Contract Management Related (CMR)", "Supplier Related (SPR)", "Planning and Compliance Related (PCR)", along with "Unethical Practice Related (UPR)" CSFs.
- Guidance to supply chain partners on their role they need to play for implementing Blockchain-in Supply Chain
- Guidance to managers in defining the right "Performance Indicators" and "Performance Measures"
- Guidance to managers on the priority in which CSFs affect implementation so as to focuson high priority CSFs first

6.3.2 Academic Implications

- This research can be used as teaching material on Smart Contract, Blockchain enabled Supply Chain in Construction sector by the academicians in Digital Technology, Construction Supply Chain and IT functional areas.
- The questionnaire used in this research could be used to conduct further empirical studiesin IT & Blockchain enabled Supply Chain.

6.4 Research Limitations

Like any other research, this one also has certain limitations. The main limitations of this research are as follows:

- In the present research, 28 constructs have been identified for the implementation of Blockchain enabled Supply Chain among Indian Construction companies. There could be certain constructs which have not been considered in this research.
- The samples taken for survey are largely located in western part in India and the responses are homogeneous in nature. There might be errors as the sample is not

geographically validated in interior part of India .

- The data collected is the personal opinion of participants and is subject to bias error.
- The data collected is from practitioners working in Construction companies operating in different product categories. Each of the product categories have different supply chain along with several challenges. Thus, the constructs could have been different depending on specific challenges in their supply chain.

6.5 Future Scope

The current research has certain limitations and there is future scope for other researchers, the same is depicted below

- Different classifications have been done for Construction companies and each type would have different supply chain challenges. Thus, future research may be done taking one type of Construction classification at a time.
- This research has been done for Construction industry and similar research needs to be done for other industries.
- In this study 28 constructs have been considered for Blockchain enabled Supply Chain, but in future research may be conducted by considering more constructs.
- The statistical tests conducted suggest adequate sample size has been considered, but future research may be undertaken by considering larger sample size. This will help in generalization of results achieved.
- The same research can be done for other geographies as this result is specific to India geography.
- This research has taken "Sector Specific" CSFs into consideration, future research may be conducted by considering more dimensions of "Sector Specific" CSFs.

6.6 Conclusion

Triple bottom line is the business performance measurement tool commonly used the industry in the modern era. In today's world, the performance of any organisation is no more limited to its financial bottom-line alone. Compliance of environment wellbeing is also one of the vital measurable key performance area (KPI) to the organisation. Unfortunately, still the awareness is largely missing in the supply chain community causing severe compromise in this area. A major reason of this negligence could be of our understanding or consideration of environment as an undemonstrative stakeholder.

Construction enterprises are recognizing the importance of Blockchain in Supply Chain. This research is carried out to understand the ground reality and CSFs affecting implementation of Smart Contract. The key finding of this research is CSFs influence implementation of Blockchain in construction Supply Chain among Indian Construction companies and improves firm performance. One more finding of the research is that "Level of Blockchain Usage" and "Extent of IT Usage" in the organization is associated with Implementation.

Unfortunately, still the awareness is largely missing in the supply chain community causing severe compromise in this area. A major reason of this negligence could be of our understanding or consideration of environment as an undemonstrative stakeholder.

Today's most of the challenges the human civilisation is facing because of the annoying behaviour of environment are the result of such unrealistic consideration over centuries. Global warming, air pollution, poor ground water recharge or ground water contamination are few examples. Dr. Li (Chinese Virologist) and many other people say the present Covid-19 pandemic may be another example of irresponsible innovation of human being which brutally impacted the civilisation and caused unprecedented damage to the supply chain environment.

Unplanned waste management in the project construction site is a very common phenomenon noticed by many of us. These unplanned wastes (construction materials, chemicals, paints, scraps etc) not only contaminate air & water but also leave a severe health threat to the people at work in the projects and nearby inhabitants.

This research has considered the importance of sector specific CSF in implementation of Blockchain based Supply Chain among Indian Construction companies. It highlights the importance of Smart Contract to drive “Environmental Bottom-Line (ENV)”, “Social Bottom-Line (SOB)” and “Economic Bottom-Line (ECB)” of business encountering Challenges in Construction SCM.

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Appendix – I

QUESTIONNAIRE

Opportunity of Blockchain technology in Construction Supply Chain Managementin India

This survey is conducted for research on "Opportunity of Blockchain technology in Construction Supply Chain Management (SCM) in India". The objective of the research is to evaluate the impact of critical factors on effective implementation of smart contract inconstruction supply chain management and to evaluate the effect of smart contracts on performance of the construction supply chain management. Accordingly, a questionnaire has been prepared where you need to rate different parameters. This will help academicians, supply chain managers, SCM & digital technology professionals and policymakers in prioritizing parameters for effectively implementing blockchain enabled SupplyChain in Construction Industries in India. The survey would take approximately 15 minutes. Your responses shall be kept confidential and would be used for research purpose only.

* Required

PART I (Personal & Company Information)

1. Name *

2. Contact Number

3. E-mail ID

4. Name of the Organization *

_____

5. Designation *

_____

6. Department *

Mark only one oval.

- Procurement Production
- Sales/Marketing/Business Development
- Finance
- HR
- Information Technology
- Safety
- Quality
- Other: _____

7. What is the nature of your company's business? (You can also select multiple responses) *

Check all that apply.

- Manufacturing
- Construction Materials
- Civil Contracting
- Mechanical Contracting
- Original Equipment Manufacturer
- (OEM)Technology Provider
- Consultant
- Trader
- Agreegator
- EPC
- Contractor
- Electrical & Instrumentation
- HVAC Contractor
- Applicator
-

Equipment Leasing

- [ ] Academic Institution
- [ ] Environment, Social and Governance
- [ ] (ESG)Safety / Quality Control/Audit
- [ ] Other: _____

8. Are you / your organisation is aware of Smart Contract / Blockchain Technology / Robotic Process Automation (RPA)? *

Mark only one oval.

- ◯ Yes *Skip to question 9*
- ◯ No *Skip to question 10*

If your organisation is aware of Smart Contract / Blockchain Technology /Robotic Process Automation (RPA)

9. If your organisation is aware of Smart Contract / Blockchain Technology / Robotic Process Automation (RPA), is it ?

Mark only one oval.

- ◯ Under consideration / discussion
- ◯ Being implemented
- ◯ Already implemented
- ◯ None of the above options
- ◯ Can't say

PART II (Impact of critical factorson effective implementation of smart contract)

The statements given below are used to evaluate the impactof critical factors on effective implementation of smart contract (SC) in construction supply chain management.
Kindly mark responses on a scale of 1-5, where

1. Will have very low positive impact on effectiveimplementation of SC
2. Will have low positive impact on effective implementationof SC
3. Will have medium positive impact on effectiveimplementation of SC
4. Will have high positive impact on effectiveimplementation of SC
5. Will have very high positive impact on effectiveimplementation of SC

1. What exactly the end-user/purchaser wants from supplier (scope of supply) *is unclear in the request for enquiry (RFQ) many a times, causing multiple communications & delay in service level agreement (SLA) without any record in system.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

2. End-user/purchaser changes the scope of supply frequently. Many a times *even after awarding of contract {Purchase Order (PO)/Work Order (WO)}, causing unnecessary delay/rework by the supplier.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

3. End-user/purchaser delays drawing approval/defers contractual supply date *(CDD)/defers inspection date, causing delay & working capital blockage at suppliers' end.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

4. Non-linking of materials/services requirements with project critical path (CPM) *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

5. Lack of consolidated procurement plans *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

6. Fragmented purchases causing high percentage of emergency procurements. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

7. Poor understanding of working capital/cash flow management at operating level *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
-

5-Very High

8. Suppliers/contractors' invoices with high percent error causing delay in bill verification, processing *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

9. Missing quality/labour/HSE policy in PO/WO. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

10. Cartelisation by suppliers/contractors. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

11. End-user/purchaser does not always clearly mention Quality assurance *plan (QAP) in RFQ /PO and rejects supply/services during inspection/post- delivery, causing loss of time & money. Lack of transparency.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

12. Missing transparency-Frequent change in delivery schedule by suppliers/contractors causing time & cost overrun to purchaser. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

13. Monopolistic approach of suppliers. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

14. Missing transparency-Frequent change in delivery schedule by suppliers/contractors causing time & cost overrun to purchaser. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

15. Delayed submission of offer by suppliers. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

16. End-user/purchaser and supplier/contractor do not collaboratively validate contract compliance at regular intervals during the contract period and get intoblame game for non-compliance in QUALITY, TIME & COST overrun.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

17. Supply of materials/services without valid PO/WO.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

18. Indulging in ethical practices (bribery) by suppliers/contractors.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

19. Deduction of liquidated damages (LD) from the supplier/contractor by thepurchaser owing to delay caused by purchaser.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

20. Traceability becomes a bottleneck. -Delay in suppliers'/contractors' paymentby purchaser without any status update, causing high cost of capital employed, especially for MSME.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

21. Cash transaction by suppliers/contractors for labour payments indulging inethical practices.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

22. Lack of periodic contract performance management.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

23. Optimise natural resources – Construction supply chain predominantly accounts for high wastage of natural resources (energy, water) and pollution (air,water, sound). Continuous training, digital tracking of usage with reward/recognition will cause in this matter.22. Lack of periodic contract performance management.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

24. Widespread non-compliance to standard operating procedures (SOP) &Absence of stadard formats and checklists.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

25. Lethargic exercise of inventory management.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

26. Lack of transperancy in MSME documentation.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

27. Ineffective project planning- purchaser and supplier/contractor do not jointlyinfluence project plan regularly, causing resource idling at both sides.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

28. Recording of safety non-compliances by supplier/contractors like ‘Near missincidents (NMI), ‘Learning from incidents (LFI) etc.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

PART III (Implementation of smart contracts affect the performance of theconstruction supplychain)

The statements given below are used to evaluate the effect of smart contracts (SC) on performance of the construction supply chain management SCM). Kindly mark the responses on a scale of 1-5, where
SC will have very low effect on performance of SCM
SC will have low effect on performance of SCM
SC will have medium effect on performance of SCM
SC will have high effect on performance of SCM
SC will have very high effect on performance of SCM

1. Creating culture of success-Knowledge sharing (technology, innovation, *best practices etc.) among the supply chain partners for the success of each other.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

2. Digital verification (bar code) of all goods supplied against e-packing slip/delivery note and online notification to supplier, followed by the identification of Over/Short/Damage/ hazardous using robotic process automation (RPA). *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
-
-

4-High

5-Very High

3. Employability improvement-The staff involved/required to handle supply *chain shall be trained to develop new skill sets which in turn will improve their employability.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

4. Health & Safety compliance recognition and reward-It improves moral of *workforce, reduces absenteeism and boosts productivity, job satisfaction & quality

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

5. Skillset development planning-It improves self-confidence, versatility & resilient supply chain ecosystem. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

*

6. Reduced material delivery lead time- Reduces safety & minimum stock level and in turn improve working capital in business which is a deterrent inMSME sector.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

7. Optimized resource utilization- It identifies Men, Machine & Material idling/misuse and improves supply chain efficiency. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

8. Commodity price trend driven procurement decision-Digital technology can efficiently predict futuristic price based on past trend and influence procurement decision. Price variation formula driven vendor payment processbrings much higher transparency and trust among the supply chain partners. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

*

9. High inventory turnover ratio- Improved SCM efficiency and resource optimization, increases inventory turnover ratio and makes the supply chain more agile.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

10. Cost saving-By collaborating with each other, the supply chain partners can revolutionize demand-supply economics and save cost. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

11. Cash-to-cash cycle-Less the cash-to-cash cycle time in SCM, less the cost of capital and more the profitability in business. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

12. Circular economy- Construction supply chain is one of the best applications of resource recycling and waste optimization. *

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

13. Digitization of all SCM documents (paperless)- Most of the supply chain *transactions can be end to end transcripted digitally at different data sources across the world encouraging paperless SCM.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

14. System based shelf-life material management-Handling shelf live *materials and utilization of the same within the expiry date is always a supply chain challenge. This can efficiently be managed through digital tracking, minimizing wastage and environmental impact.

Mark only one oval.

- 1-Very
- Low2-Low
- 3-Medium
- 4-High
- 5-Very High

15. Digital signing of contract documents- Saves time, cost and natural resources. *

- 1-Very Low
- 2-Low
- 3-Medium
- 4-High
- 5-Very High

16. Supply of materials in lots as per consumption plan-Logistic and warehousing are two of the major costs and environmental concerns in SCM. If the materials are optimized, bunched and supplied as per the consumption plan, it can add value in environmental bottom-line. *

- 1-Very Low
- 2-Low
- 3-Medium
- 4-High
- 5-Very High

17. Lesser waste generation – Analytical material planning based on annual requirement logic, translucent stock visibility & auto PO generation with thehelp of digital technology will definitely minimise waste generation in construction SCM *

Mark only one oval.

- 1-Very Low
- 2-Low
- 3-Medium
- 4-High
- 5-Very High

Appendix – II

PUBLISHED ARTICLE FROM RESEARCH WORK

Neuro Quantology | September 2022 | Volume 20 | Issue 9 | Page 5608-5619 | doi: 10.14704/nq.2022.20.9.NQ44655
Prasanta Kumar Gupta and Dr. Mohd Imran Khan/ Sustainable Supply Chain by Optimizing Warehouse Capacity Utilization - A Blockchain Solution

Sustainable Supply Chain by Optimizing Warehouse Capacity Utilization - A Blockchain Solution

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Abstract

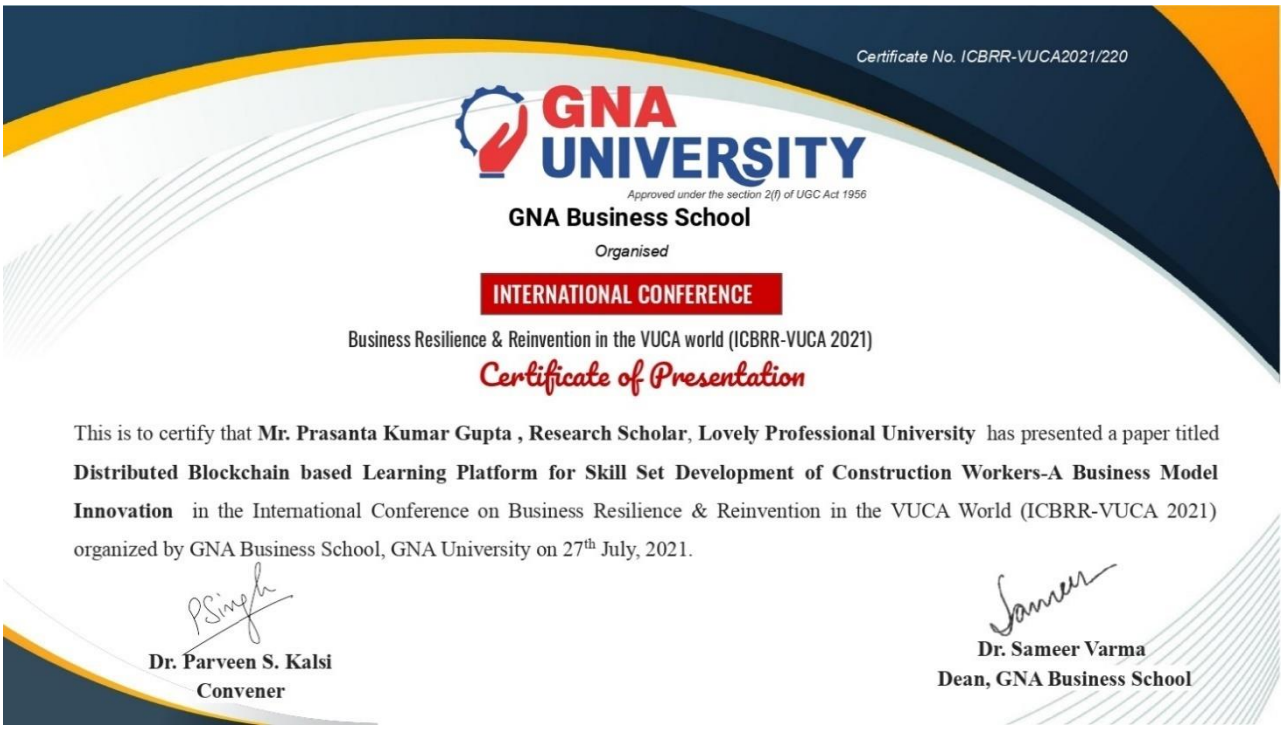
In India supply chain is effective but not efficient. Warehouse being one of the integral components of supply chain and constitutes about 15%-35% of logistics cost, its importance is significantly high in the efficiency improvement of supply chain. Logistics cost in India is 14% of GDP compared to 8% in USA. As per NITI Aayog, if India achieves its goal of reducing logistics cost to 10%, it can save INR 10,000 billion during 2022-2025. Indian warehouse sector is expected to grow from INR 1501.2 billion in 2019 to INR 2821 billion by 2024 at a CAGR of 13.57%. The highest growth is envisaged in agriculture warehouse from INR 145.82 billion in 2019 to INR 365.75 billion by 2024.

Indian cold storage industry is confined mostly in 6 states. 90% cold storages are controlled by unorganized sector where most of the warehouses are less than 10000 square feet in size, not energy efficient/environment friendly and suffer underutilized causing high operating cost to the owner. During ongoing vaccination drive, Government realized the inadequacy of cold storages across the country and initiated infrastructure development for future readiness. As per Indian Agricultural Research Institute (IARI), 30%-40% of the vegetable & fruits and almost 10% of the agricultural produce go to waste which would have doubled the productivity and income of farmers. IARI invented a solar refrigerator which can preserve 2 Tons fruits, vegetables and flowers.

Connecting the agriculture warehouses and cold stores across India in Hyperledger Fabric blockchain will improve capacity utilization and help the farmers to directly reach out to cold stores/warehouses bypassing the mediators.

Keywords: *Sustainable, Warehouse, Cold stores, Capacity, Optimize, Blockchain, Hyperledger.*

DOI Number: 10.14704/nq.2022.20.9.NQ44655 **Neuro Quantology 2022; 20(9):5608-5619**



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Certificate of Presentation

This is to certify that **Mr. Prasanta Kumar Gupta , Research Scholar**, **Lovely Professional University** has presented a paper titled **Distributed Blockchain based Learning Platform for Skill Set Development of Construction Workers-A Business Model Innovation** in the International Conference on Business Resilience & Reinvention in the VUCA World (ICBRR-VUCA 2021) organized by GNA Business School, GNA University on 27th July, 2021.

Dr. Parveen S. Kalsi
Convener

Dr. Sameer Varma
Dean, GNA Business School

IIM NAGPUR

ISDSI GLOBAL

CERTIFICATE OF PARTICIPATION

This is to certify that

Prasanta Gupta

Lovely Professional University

Presented the paper titled

Sustainable Supply Chain by Optimizing Warehouse Capacity Utilization - A Blockchain Solution

at the

ISDSI-Global Conference 2021: Leading business in a FLUID world

held at **INDIAN INSTITUTE OF MANAGEMENT NAGPUR** from December 27-30, 2021

Dr. Arun Elias	Dr. Ramachandran Natarajan	Dr. Prakash Awasthy	Dr. Gunjan Tomer
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This is to certify that Dr./ Mr. / Ms. **Prasanta Gupta**

of **Research Scholar, Mittal School of Business, India**

has participated and presented paper titled **Skillset development of workers in mechanized construction sector- A responsible and sustainable blockchain technology solution**

in the International Conference on "**INDUSTRY 5.0: HUMAN TOUCH, INNOVATION AND EFFICIENCY**" held on January 28, 2022 organized by Mittal School of Business, Lovely Professional University, Punjab.

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Prepared by
(Administrative Officer-Records)

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Dr. Rajesh Verma

Conference Director
Dr. Sanjay Modi

Graphical Abstract Submission Form

Title of the Graphical Abstract: Implementation of Blockchain in Supply Chain

Authors name: Prasanta Kumar Gupta, Dr. Mohd Imran Khan

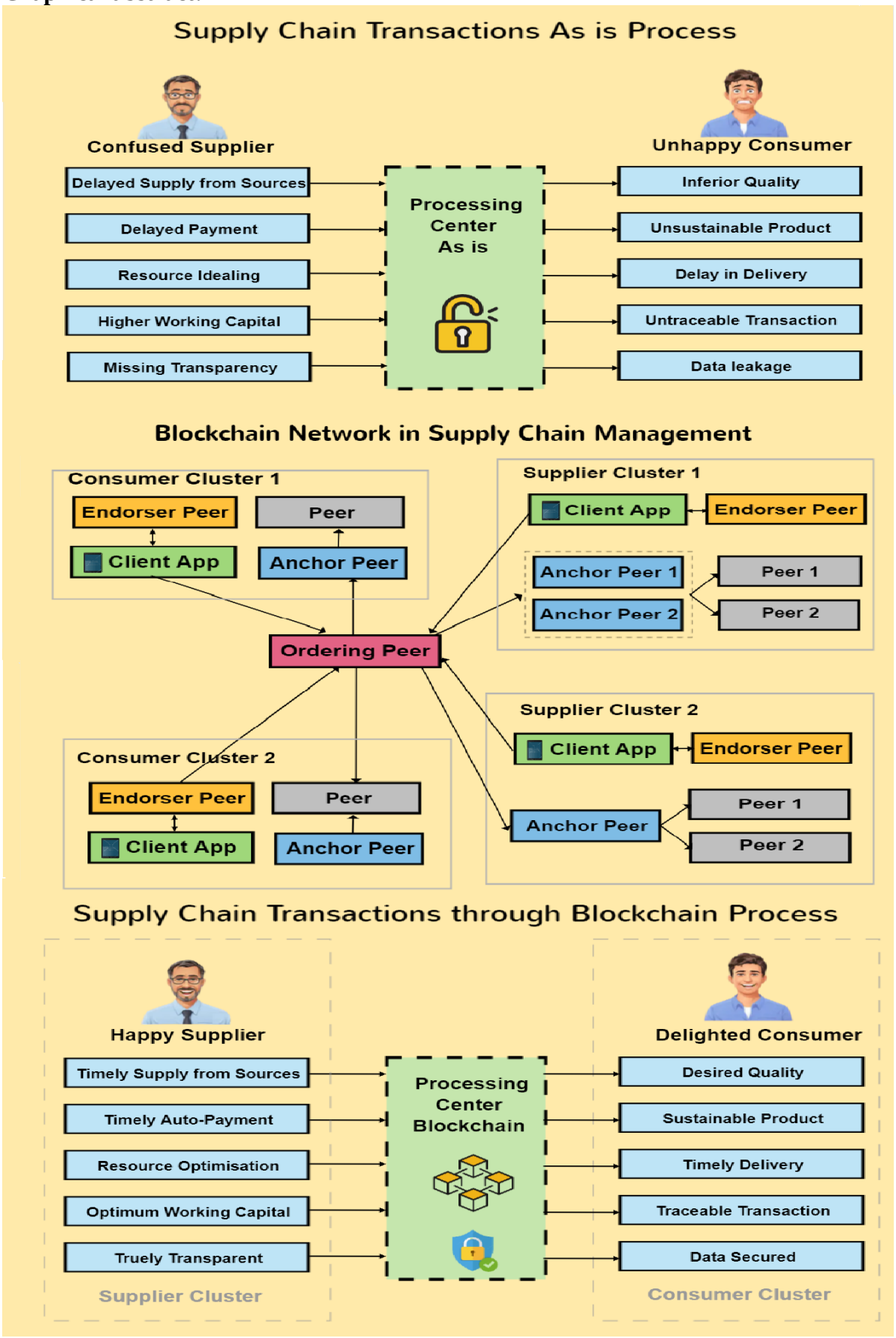
Name of Scholar: Prasanta Kumar Gupta Registration Number: 41800886

Program Name: PhD in Management

Name/ UID of Supervisor: Dr. Mohd Imran Khan, 24973

Summary of graphical abstract: In today's complex and competitive business world, supply chain of any organization works under tremendous pressure warranting availability of right product of right quality & right quantity from the right source at the right place at right time and right price (7R). The major challenges in supply chain management are data security, transparency and traceability. Supply chain management is accountable for movement of materials and or services from the point of origin to the point of consumption, meaningfully connecting all the stakeholders in the complete journey. A finished goods reaches consumers through many mediators like whole sellers, Stuckists, agents, retailors etc. whereas the different raw materials required in the process come from numerous tiers of suppliers. In case of a defect in the finished goods experienced by a consumer, the traceability of the origin of the defect becomes extremely difficult generating huge amount of confusion to suppliers and dissatisfaction to customers. Blockchain enabled supply chain can provide easy solution to this intricate problem because blockchain locks complete data/details in a block at every transaction ensuring data security, transparency and traceability. Blockchain is a decentralized and tamperproof data management system which is shared across a network of computers known as peers and each computer is called a node.

Graphical abstract:



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