Role of Industry 4.0 in Project Management

Priyanka Verma, Miral Parikh
NITIE - National Institute of Industrial Engineering
Mumbai, India
priyankaverma@nitie.ac.in, miral.parikh.2020@nitie.ac.in

Vijaya Dixit
Indian Institute of Management, Ranchi, India
movijaya@gmail.com

Abstract

In today's era, project management has become one of the vital fields in evaluating the success of a project. It has become crucial to forego traditional project management techniques and adopt modern tools and technologies due to the intense competition between companies to enhance the efficiency and productivity of their processes. To achieve this, it is essential to reduce project risks involved and to make more in less time. Industry 4.0 is revolutionizing the traditional methods with the advancement in technologies and automation reducing manual intervention. This study utilizes the novelty, technology, complexity, and pace (NTCP) framework for the project classification based on different project characteristics to identify the risks involved during the life cycle of the project. This research presents a case study of company XYZ based in India, to analyse the role of Industry 4.0 in project management by comparing the risk profiles of a project with and without the role of Industry 4.0 tools and technologies. It also analyses the risks involved in implementing Industry 4.0 technologies in project management. The study also paves the way for further research and adoption of Industry 4.0 in project management across different sectors.

Keywords
Project Management, Industry 4.0, NTCP framework, Construction Industry, Risk classification

1. Introduction
Project Management has been one of the most significant aspects in deciding the success of any project. The fate of project management will be intensely affected by technological leaps forward. Particularly, implementing Industry 4.0 tools and technologies in project management is turning out to be increasingly testing as a result of developing new advances. Recent innovations have made a lot of things in life simpler; however, they have impacted the management of companies. To lay it out plainly, they have changed project management in every possible way. Due to the use of these Industry 4.0 technologies, it has become possible to achieve more in less time than ever before. To ensure the best competitiveness, the integrated management of the projects will become increasingly important, and, as a result, the project teams will become more and more focused on specific objectives related to diverse elements of Industry 4.0 (Win et al. 2018). According to Win et al. 2018, it will be compulsory to get along with fast adaptable and flexible production processes to adapt quickly to the demands of the market. In order to adapt to the increasingly dynamic demands of the market, it will be necessary to reduce project risks by implementing Industry 4.0 tools and technologies in project management. To address this issue, this work aims to develop a risk profile of a plant construction project based in India with the use of the novelty, technology, complexity, and pace (NTCP) framework for the project classification. This risk profile will be analyzed with and without the implementation of Industry 4.0 in project management of the construction plant. This study compares the probability-impact (PI) matrix of the two scenarios to assess the changes in impact and importance level of the risks.

To understand processes involved in the project and to analyze the NTCP dimensions and risks involved with and without the implementation of Industry 4.0 technologies in project management, a case-based approach is adopted by conducting 4 personal interviews with Mr. ABC, working as a Senior Engineer at XYZ Company for 5 years. The interview discussion was broadly focused on three areas as follows: a) Basic details of the company and information of the project, b) NTCP Dimension and risks involved, and c) Use of technologies. Based on the discussion, the NTCP model and PI matrix of risks were developed.

This research aims to analyse the role of Industry 4.0 technologies in project management at XYZ. To achieve this, a 5-step methodology is followed. In the first step, the project is classified based on the NTCP Framework without the application of Industry 4.0 in project management. Based on this classification, the risk profile is developed and analysed for the project without the application of Industry 4.0 in Project Management. In the next step, the NTCP Framework and the risk profile are developed and analysed with the application of Industry 4.0 in project management. With the NTCP dimensions, Diamond models are plotted for both NTCP Framework. In the last step, Probability Impact matrices for project risks are developed and analysed without and with the application of Industry 4.0 in project management. Based on these matrices, risks in implementing Industry 4.0 technologies in project management are discussed.

2. Literature Review

2.1 Project Complexity

The conventional project classification frameworks have been based on sectors, the scale of the project, innovation, product development, size of resources, etc. Henderson and Clark (1990) classified projects based on the degree of innovation. Irrespective of the industry type, the different levels of innovation considered for projects are radical, incremental, modular, and architectural projects. Turner and Cochrane (1993) discussed project goals and work methods as two new dimensions for defining project types. These dimensions had been overlooked earlier. The absence of a standard framework providing specific guidelines for the management of a distinct project is discussed by Shenhar (1993) and Shenhar and Dvir (1996). The authors also challenged that the universal concept of "one size fits all" is not suitable for managing distinct projects, such as R&D and construction projects. The above studies had limitations because they did not view project holistically from multiple dimensions for its classification.

Shenhar and Dvir (2007) proposed the four-dimensional NTCP framework for selecting project management strategies based on its classification type. The NTCP framework covers all essential project characteristics for the selection of appropriate project management type and also enable the identification of project risks. The management of project risk over its life cycle helps the project remain on track and meet its goal. Rodrigues-Da-Silva and Crispim (2014) discussed that risk management in projects is a practice by which it is managed under certain conditions (time, cost, and quality parameters' set). A theoretical framework was developed to classify and associate best practices for each phase of the project life cycle. Project risk management can be done by taking into consideration of organizational maturity and project complexity. A study by Rabechini and Carvalho (2013) has shown that risk management practices have a considerable impact on project success. They also discuss that the presence of a risk manager has a positive impact on project success. Therefore, the present study adopted the NTCP framework for project classification.

2.2 NTCP Framework

The NTCP framework is used for project classification and envelops all project attributes that have been distinguished to be significant for the choice of suitable project management aspects and can empower the identification of risks. By understanding the particular risks and vulnerabilities applicable to a specific project, we can break out the basic segments and work in the most appropriate way to build our opportunity of achievement. It a generic framework which can be adopted for a broad range of projects (Shishodia et al. 2018). It is an organized structure that can be utilized when settling on choices about projects and how they should be executed. It additionally permits the correlation between the present model of management and what is really required for the project.

Table 1. NTCP dimension levels

NTCP Dimension	Level No.	Level	Level Description
Novelty: How new is the product to the market	1	Derivative	Extension or Improvement of an existing product
	2	Platform	A new generation of an existing product line or a new type of service
	3	Breakthrough	A new-to-the world product
Technology: Extent of new	1	Low-tech	No new technology is used. Well established and mature technologies

technology to the company used by the project	2	Medium-tech	Mostly existing technologies, limited new technologies or a new feature
	3	High-tech	All or mostly new, but existing technologies
	4	Super High-tech	Necessary technologies do not exist at project initiation
Complexity: How complex is the product	1	Assembly	Subsystem, performing a single function
	2	System	Collection of subsystems, multiple functions
	3	Array	Widely dispersed collection of systems with a common mission
Pace: Project urgency and available timeframe	1	Regular	Delays not critical
	2	Fast-competitive	Time to market is important for the business
	3	Time-critical	Completion time is crucial for success-window of opportunity
	4	Blitz	Crisis project- immediate solution is necessary

NTCP Framework is based on four dimensions (Table 1) which are explained below in detail:
(i) Novelty: This dimension measures the vulnerability of the project's objective, the vulnerability in the market, or both. It gauges how new the project's item is to clients or to the market and, subsequently, how precise and characterized the underlying product necessities are. Novelty assists the managers to take decisions about:

a. Time needed to finalise product necessities
b. Accuracy & reliability of market data and its authenticity

(ii) Technology: It measures the project's technology uncertainty level and the novelty of technology required in the project. Technology assists the managers to decide:

a. Time needed to finalise design
b. Impact of the technical systems
c. Technical abilities and skills needed by the project team

(iii) Complexity: This dimension measures the intricacies of the product, the systems, and the project company. Complexity assists the mangers to decide:

a. Framework of the company
b. Manage the complexity of the project

(iv) Pace: This dimension measures time available to complete the job and the urgency. Pace assists the managers to decide:

a. Procedure of planning
b. Timing of reviews and how they should be conducted
c. Optimal of involvement of top management in the projects

The Diamond Model:
The above four dimensions, when plotted on a graph, represent a diamond-like structure, and hence NTCP Framework is also called the Diamond Model. The diamond size depicts the risk level, and the larger is the size of the diamond, the higher is the risk involved.

The achievement of project management relies upon its right characterization during the initial stage. The difficulty is to accurately order the project as indicated by the four measurements. The NTCP system doesn't show apparent criteria or calculations that may help with playing out this grouping. The right characterization of a project is profoundly subject to the evaluator's understanding and instinct. The project administrator must be experienced or should employ an accomplished advisor to get the correct grouping of the project. The levels of risk in a project have to be identified by the project manager in order to map it on the diamond graph.

2.3 Industry 4.0 Technologies

The induction of the IoT into the production and manufacturing environment has marked as fourth industrial revolution, referred to as Industry 4.0. The five significant highlights of Industry 4.0 are digitization, advancement, and customization of production; robotic automation and adjustment; human-machine collaboration and interaction (HMI); services including administrations and organizations; and programmed information trade and correspondence. These highlights are not exclusively profoundly associated with web advances and propelled calculations; however, they additionally demonstrate that Industry 4.0 is a modern procedure of significant worth, including information management. The key technologies, transforming the manufacturing as well as the service industry, are discussed as per the literature review.

Big data usually contains loads of unstructured data that demand more real-time analysis, as well as offering new opportunities to uncover new values, helping us gain a comprehensive understanding of hidden values. It is generating new challenges, such as how to effectively organize and handle these datasets (Liu et al. 2014). Big data is a term for huge, more diverse and complex data sets with difficulties in processing, analyzing and visualizing for further processes or outcomes (Sinanc and Sagiroglu 2013). Big Data is a series of large data sets with a vast range of styles, making it impossible to process using state-of-heart data processing techniques or conventional machines for data processing (Chen et al. 2014).

ASTM has described additive manufacturing (AM) as a process of combining materials to create artifacts from three-dimensional model data, typically layer by layer, as opposed to subtractive methods of manufacturing. Three-dimensional printing is a manufacturing process in which materials such as plastic or metal are deposited in layers on each other to create a three-dimensional object, such as pairs of eyeglasses or other 3D objects. It starts with a meshed 3D virtual model that can be generated from acquired image data or structures designed into virtual-aided software (CAD) design. Commonly, an STL (Surface Tesselation Language) file is developed. The mesh data will be further sliced into a build file of two-dimensional layers and sent to the three- dimensional printing machine (Xin et al., 2016).

Augmented Reality (AR) helps the user to see the real world, with virtual objects superimposed or constructed. The virtual objects represent information which the user cannot detect through his own senses directly. The knowledge that the virtual objects transmit lets a user perform activities in the physical world (Azuma 2004). The goal of Augmented Reality is to streamline the usage by taking virtual knowledge of user (Carmigniani et al. 2010).

Virtual Reality (VR) is a technology, which is often seen as a natural extension of specialized input and output tools to 3D computer graphics. Virtual reality can be described in very simple terms as a digital or virtual environment that gives a person a sense of reality. Simulated, interactive, and multidimensional environments are created using advanced technologies in VR. Visual interfaces comprising screen monitors and head-mounted displays (HMDs), haptic interfaces & real-time motion tracking gadgets are used to build environments that allow users to interact in real-time with images and virtual objects across multiple sensory modalities (Sveistrup 2004).

Cloud computing is a model for enabling easy, on-demand network access to a familiar pool of configurable computing resources (e.g., networks, servers, storage, software, and services). It can be easily supplied & released with minimum managerial effort or service provider involvement (Dillon et al. 2010). A large-scale distributed computing model powered by economies of scale in which a pool of abstracted, virtualized, dynamically scalable, controlled computing resources, storage, platforms, and services are provided over the Internet on-demand to external customers.

IoT coordinates different gadgets outfitted with detecting, recognizable proof, preparing, correspondence, and systems administration abilities (Trappey et al. 2017). It incorporates machines and gear, sensors, the cloud, and terminals. An IoT framework is equipped for offering specific and customized items. Webservers transmit information to the modern cloud and plants using wired or remote systems. Once the information is received, the producer will coordinate a plan and will operate the creation procedure to deliver items proficiently. The performance can be further improved with the help of self-advancement and autonomous decision-making instruments.

3. Case Study

The case study approach is best to ensure that the data collected and analysed is empirical and that the research outputs and the proposed analyses are of real value. The case study chosen for this research is of engineering, procurement,

and construction company. Names and any details that could lead to the identification of the company and the interviewee executive are anonymized. Therefore the company is called XYZ, and the executive is called Mr. ABC. A brief profile of the XYZ Company and the executive are described in Table 2.
.

Table 2. Profile of the company and the executive

Name of the Company	*XYZ Pvt. Ltd.*
Industry	Engineering, Procurement and Construction
Products/Services Offered	Cement Plant, Chemical Plant & Processes, Fertilizer, Metallurgy Plant
Establishment Year	1921
HQ Location	Vikhroli, Mumbai
Plant Location	Rayagada, Odisha
Project Details	Construction of Alumina Plant of capacity 0.5 MT per annum
Name of the Executive	*Mr. ABC*
Designation	Senior Engineer
Experience in years	5+ years
Qualification	B.Tech. - Instrumentation, Thadomal Shahani Engineering College, Mumbai

XYZ is a main accomplice for the building, development, and administration of industrial plant. As a team with its clients, it creates top-quality arrangements and conveys proficiency, unwavering quality, and supportability over the whole life cycle. Its worldwide system empowers them to supply turnkey plants worldwide that set benchmarks as far as worth included and asset well-disposed advancements. They have arranged and constructed 2,500 plants all over the world.

With regards to the planning, development, and administration of modern plants, frameworks, and hardware, XYZ is one of the world's driving full-specialist co-ops. It offers their clients single-source obligation along the whole worth chain. Notwithstanding compound, coke, concrete, and other modern plants and treatment facilities, its portfolio likewise incorporates mining, metal preparing, and port taking care of gear alongside relating administrations. It has built up a worldwide reputation as an EPC (Engineering, Procurement, and Construction) pioneer. It bolsters clients in the development of modern plants with its thorough scope of administrations, from showcase studies to the finishing of turnkey plants and advertising of the items. It likewise offers significant extra administrations including area choice, financing, arrangements with specialists, support, wellbeing examinations and innovation, specialized management, preparing of working faculty, and project management.

3.1 Project (P1) Details: Construction of Alumina Plant of capacity 0.5 MT per annum

In February 2018, XYZ was awarded a contract by PQR to provide EPC services for an alumina refinery expansion project at Rayagada in Odisha, India. The expansion project aimed to increase the plant's total processing capacity by 0.5 MMTPA to 2 MMTPA from 1.5 MMTPA. The raw material, bauxite, for the process, was sourced from PQR's mines in Odisha. The alumina from the complex is to be used in PQR's sister company's aluminium smelters at different locations to produce aluminium products.

The estimated project duration is 30 months, from December 2018 to June 2021. The actual project was executed traditionally with low-technology and does not involve the use of Industry 4.0 technologies in project management. The primary project management tools and techniques used were MS Office, 3D modelling and review software, proprietary tools, and basic internet functionalities such as email, video conferencing, etc. The project involved highly complex chemical processes, huge equipment, multiple external stakeholders, and various functional teams such as plant design, civil, electrical, mechanical static equipment, rotary equipment, piping, instrumentation, process, material handling, and firefighting.

3.2 NTCP Framework and Risk Profile

The process to analyze the role of Industry 4.0 in project management and the risk profile of the project is as follows.

3.2.1 Step 1: NTCP Framework without the application of Industry 4.0 in Project Management

Construction projects are mind-boggling and include questionable conditions all through the project lifecycle, for example, climate variances, expansion, fluctuating overall organization revenues, advertise rivalry, subcontractor postponements, and disappointments, and on-location efficiency. These vulnerabilities, in the end, bring about project postponements and cost invades, and incidentally in the period before project finishing.

XYZ has decent experience in executing the construction of metallurgy projects. Hence, this project can be viewed as a "Derivative" as the novelty dimension of NTCP framework. It was a usual construction project with standard equipment used for construction, and no new technologies were used. Therefore, it can be identified as "Low-tech" on the technology dimension of NTCP. As per Mr. ABC, "thousands of kilometers of pipelines were running throughout the plant connected to columns, vessels, instrumentation, pumps, compressors, etc.". So, there were hundreds of processes forming systems and sub-systems with thousands of components and kilometers of pipelines. The coordination degree and integration necessary for components and systems were very complex. Therefore, the project is classified as "Array" on the complexity dimension of NTCP. Based on the experience of Mr. ABC he commented that "the process of manufacturing alumina is not novel since it is a commodity and can be easily manufactured by its competitors." Hence, the time required for market entry is significant in order to capture the market. Therefore, the project can be considered as a "Fast competitive" on the pace axis of NTCP (Table 4).

3.2.2 Step 2: Analysis of Risk Profile for the project without the application of Industry 4.0 in Project Management

Based on the above NTCP project classification and experience of the interviewee, it is derived that for projects characterised as derivative, low-tech, array & fast-competitive as per NTCP framework, outsourcing, resource, legal and regulation, cybersecurity, and delay risks are more impactful relative to others. It is because of delayed outsourcing, the likelihood of hacking of the centralised server, and stringent guidelines of legal authorities. The detailed analysis of the major risks involved during the execution of the project is as follows. The probability of occurrence of a risk and its impact levels are also recorded for the following risks (Table 3).

Table 3. Definition of project risks

Code	Type of Risks	Definition for the Project
R1	Cybersecurity & Data Privacy Risk	Risk of manipulating centralised server and stealing data
R2	Delay in Project Completion Risks	Delay in plant commissioning and production
R3	Estimation of Deadlines Risks	Risk due to missing important project milestone deadlines
R4	Fraud Risk	Risk due to payment and material frauds
R5	Hardware Infrastructure Risks	Risk due to the breakdown of equipment and plant infrastructure
R6	Legal & Regulatory Risk	Changes in construction regulations
R7	Operational & Credit risk	Risk of default in debt payment and operational issues
R8	Outsourcing Risk	Risk due to outsourcing packages from external vendors
R9	Resource Risks (Money/People)	Unexpected costs & risk due to unavailability of skilled people
R10	Tech Infrastructure Risks	Software issues and downtime in systems

Since XYZ is familiar with the work environment due to its past experience, fraud risk has a low probability of occurrence, but in case a fraud is encountered, it can have a high impact on the overall project. Cybersecurity is of utmost importance since the entire plant can be controlled via centralised server in case it is hacked. Since there is no advanced technology used to strengthen cybersecurity, the probability of occurrence is almost certain, and its impact will be high. During the construction of the plant, it is mandatory to build landfills for the dumping of hazardous chemical wastes as per the regulations. Because of the complicated legal rules and regulations, this risk is likely to occur, having a significant impact on the entire project. Risks associated with outsourcing, resource, and operations have high impact, and the probability of occurrence is very likely since it involves a lot of dependence on external vendors, huge resources (in terms of money and people), and very complex operations due to the size of the plant. The risk associated with the estimation of deadlines can lead to delay in project completion risk, which is almost certain to occur and has a medium impact on the project. The unrealistic deadlines and outsourcing delays make the project vulnerable to risks associated with them, which impedes the project's success. Because of the use of insufficient technology, the risks associated with tech infrastructure and hardware infrastructure are likely to occur and will have a medium impact.

3.2.3 Step 3: Modification in the NTCP Framework and Analysis of Risk Profile with the application of Industry 4.0 in Project Management

Based on the above analysis, it can be concluded that XYZ is yet to adopt Industry 4.0 tools and technologies in project management. But as per Mr. ABC's comments, we observed that XYZ has already started exploring the advantages of implementing Industry 4.0 technologies and its opportunities.
As per our discussion and the scope of the project, the possible Industry 4.0 technologies, which can be utilized in its project management are as follows:

1) Blockchain:
Outsourcing risks can be reduced with Blockchain technology-enabled Service Level Agreement (SLA) management, which can increase efficiency, speed, and accuracy. It will enable the companies to digitize every component of the contract and validate the service, keeping its pace to the ground. Payment systems can also be tied up with SLAs on a blockchain, which would increase the efficiency of outsourcing contract management. Operational risks can also be decreased by using blockchain since it increases accountability and transparency in processes. Every single operation in the entire process will be recorded in the blockchain for anyone to check.

2) Augmented Reality:
It can assist with gathering continuous information of framework or hardware, which can upgrade the right dynamic. The collected information assists in recognizing the distinction between the arranged and current status of the project. (Ahmed et al. 2017). Along these lines, the AR assists with checking hazards identified with the development project as a deferral in project exercises. The AR likewise supports to improve proficient preparing, influence consumer loyalty, keep away from revision, and increment the cost sparing as a project gets finished in time, with quality.

3) Internet of Things (IoT):
IoT can be useful for behaviour tracking of equipment/systems. Hardware infrastructure risks can be reduced with the application of predictive maintenance, which involves condition monitoring of system or equipment. If there is a deviation in normal values of parameters, the system provides a suitable solution based on the huge past data.

4) Big Data and Cloud Computing:
Large information generated from Big Data assists with recognizing the various dangers associated with a development project, for example, indistinct structure subtleties and particulars, free power over subcontractors, monetary hazard, and group execution. Cybersecurity risks can be greatly reduced with the help of cloud computing. It permits information to be imparted to just the approved clients anyplace whenever. It likewise guarantees the significant level of secure exchange of information. The SaaS (Software as a Service) can offer beneficial applications and administrations, for example, email management, client relationship management, undertaking asset arranging (Ward and Sipior, 2010) with the most significant level of security, which can diminish the information loss of the project.

After discussing the potential of the above Industry 4.0 technologies in project management, the revised probability of occurrence (1 being the lowest and 5 being the highest) for each risk and its level of impact on the project were recorded (Table 5).

Table 4. NTCP dimensions for the project

Dimension	Type	Level	Dimension Reasoning without Industry 4.0	Dimension Level without Industry 4.0	Dimension Reasoning with Industry 4.0	Dimension Level with Industry 4.0
Novelty	Derivative	1	Decades of experience in the construction of metallurgy plant	1	No significant change in the production system	1
	Platform	2				
	Breakthrough	3				

Technology	Low-tech	1	Project was executed with standard designs and construction equipment available	1	Industry 4.0 technologies will require advance & complicated tech infrastructure & highly skilled team	3
	Medium-tech	2				
	High-tech	3				
	Super high-tech	4				
Complexity	Assembly	1	Degree of coordination & integration of components, sub-systems was very high	3	The overall complexity of the project will remain high	3
	System	2				
	Array	3				
Pace	Regular	1	Time taken to enter the market is very important in order to capture the market	2	Time taken to enter the market will be still important since the final product would be the same	2
	Fast/Competitive	2				
	Time-critical	3				
	Blitz	4				

Table 5: Probability Impact (PI) rating of project risks

Code	Type of Risks	Without Industry 4.0 Technologies		With Industry 4.0 Technologies		
		Probability (1 - 5)	Impact	Probability (1 - 5)	Impact	Technology Used
R1	Cybersecurity & Data Privacy Risk	5	High	3	Medium	Cloud Computing
R2	Delay in Project Completion Risk	5	Medium	3	Low	AR, IoT
R3	Estimation of Deadlines Risks	5	Medium	3	Low	Big Data
R4	Fraud Risk	2	High	2	High	-
R5	Hardware Infrastructure Risks	4	Medium	2	Low	IoT
R6	Legal & Regulatory Risk	4	High	2	Medium	-
R7	Operational & Credit risk	3	High	2	Medium	Blockchain, AR
R8	Outsourcing Risk	4	High	3	Medium	Blockchain
R9	Resource Risks (Money/People)	5	High	3	Medium	Big Data
R10	Tech Infrastructure Risks	4	Medium	2	Low	Cloud Computing

Modification in the NTCP Framework:
The application of the above technologies shifts the technology dimension of the project from "Low-tech" to "High-tech" since these technologies are existing but entirely new for XYZ (Table 4).
An increase in the technology level increases the efficiency, speed, and productivity of processes, but it also increases the risk of high dependence on skilled employees and the cost associated with it.

3.2.4 Step 4: Diamond model of the NTCP Frameworks

The Diamond model (Figure 1) based on the NTCP Dimensions for the project in Table 4 is as follows:

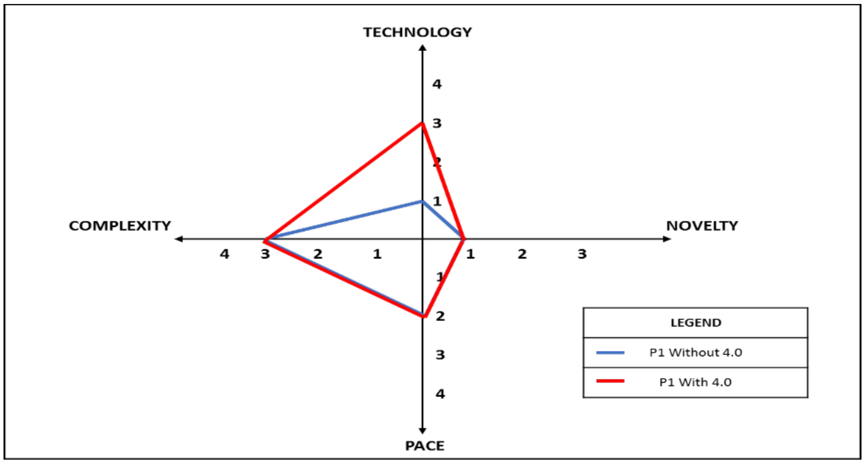

Figure 1. Diamond model for the project

3.2.5 Step 5: Analysis of Probability Impact (PI) Matrix

Probability Impact Matrix (Table 6 and Table 7) is developed to understand the importance of risk occurrence and its level of impact on the project.

Table 6. PI Matrix for the project without application of Industry 4.0

Almost Certain		R2, R3	R1, R9
Likely		R5, R10	R6, R8
Possible			R7
Unlikely			R4
Almost certain not to happen			
	Low	Medium	High
Probability	Impact		

Table 7. PI Matrix for the project with the application of Industry 4.0

Almost Certain			
Likely			
Possible	R2, R3	R1, R8, R9	
Unlikely	R5, R10	R6, R7	R4
Almost certain not to happen			
	Low	Medium	High
Probability	Impact		

Based on the above PI matrices, it can be inferred that the implementation of Industry 4.0 technologies can significantly reduce the likelihood of risks and its impact level on the project. The above heat maps indicate that the high-intensity probability-impact risks R1, R2, R3, R6, R8, and R9 can be reduced to medium and low intensity by leveraging IoT, Cloud Computing, Big Data, AR and Blockchain technologies. It is also depicted in the above matrices that the probability-impact of risks R5 and R10 has been decreased from medium to low level. It significantly increases the success rate of the project.

Cloud computing can capture real-time data from multiple sources and secures data. This data can be shared with authorized users irrespective of where they are and at what time. It also make sure that the data has a secured transaction. Cloud computing services such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and

Software as a Service (SaaS) enhances the cybersecurity and data security, thereby reducing the technology infrastructure risks (R10). Heiser and Nicolett (2008) have discussed the role of cloud computing in storing and processing data in multiple unspecified locations. These data are often sourced from unnamed providers and are from multiple customers. Thus, data transfer is secured by cloud computing with the help of encryption logic, thus reducing the cybersecurity and data privacy risk (R1).

The environmental, design, operational, and technical risks of the project can be monitored by Augmented Reality (AR). It can be done by collecting real-time data of any system, thus assisting in decision making (Rane et al. 2019). The collected data helps to identify the gap between the planned and actual status of the project. Results from this are compared and presented in AR environment to indicate the status of work as per the status of schedule (Ahmed et al. 2017). Hence, AR can help to monitor delays in project completion risks (R2). Other benefits of AR are to improve professional training, improve customer satisfaction, rework minimization, and increase of cost-saving. Overall it ensures the completion of the project on time and with the required quality. With the help of IoT, systems can be monitored in real-time. Cameras can be installed on the construction site to track inventory, human resources, and construction status. The pictures and videos of the site can be captured at regular intervals, which can help to monitor delays in the project. IoT can also be leveraged to reduce hardware infrastructure risks (R10) with the help of sensors installed on equipment which can measure thousands of data points per minute. The data captured can be analyzed, and based on it, corrective actions can be taken to increase the uptime of equipment, enhance performance, and its overall durability.

Big Data is high volume, velocity, and variety of data, which depicts the variations in data with respect to time that can be useful to predict anomalies occurring in the system, and remedial measures can be taken to prevent it from occurring (Rane et al. 2019). This data is captured from multiple sources and at various phases of the construction project, which helps in estimating the deadlines (R3). The patterns analysed from the big data can also help to identify the different risks involved, such as inefficiency in the performance of employees, subcontractors, and financial risks (R9). Blockchain technology can be leveraged to enable Service Level Agreement (SLA) management, which can increase efficiency, speed, and accuracy, increasing the efficiency of outsourcing contract management. Thus, it can reduce outsourcing risks (R8).

As discussed above, for a construction project, delay in project completion, outsourcing, and data risks have potentially harmful effects on the success rate of the project. These barriers can be overcome with the application of the above technologies in project management. Figure 2 illustrates the reduction in project risks probability of occurrence and their impact (1 being the lowest and 3 being the highest) on the overall project with the application of Industry 4.0 tools and technologies.

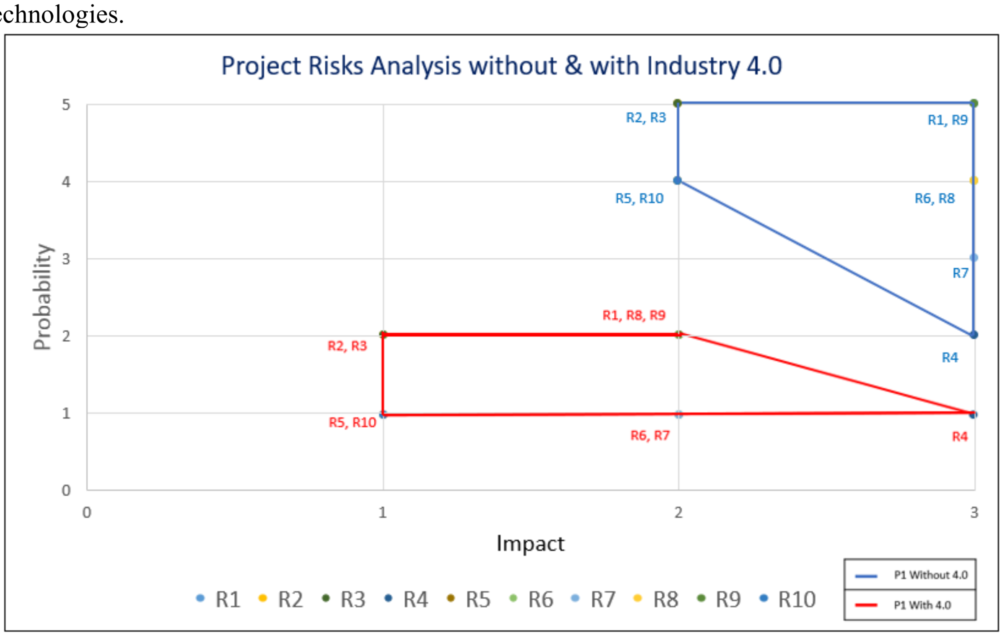

Figure 2. Comparison of Project Risks without and with Industry 4.0

3.3 Risks in Implementing Industry 4.0 Technologies in Project Management

Industry 4.0 is comparatively new for project management. In view of new methodologies, altered systems, progressively complex IT framework, etc, new sorts of risks may occur. Much of the time, the usage of Industry 4.0 has indicated that the associations between people, frameworks, and articles have gotten an increasingly mind-boggling, dynamic, and continuous enhanced system. Then again, there is a great deal of information volume and accessibility improvement continuously, which causes new prerequisites of the framework, management, advances, etc. Industry 4.0 advancements are joined by multifaceted nature and vulnerability in various manners. For instance, the establishment of AR innovation requires specific frameworks with high processing force and programming aptitudes, which requires high capital expense and mastery. Large information has a few restrictions identified with security, transferability, connections, and irregularity in information, and it likewise needs high arrangement frameworks and cutting-edge innovations to catch, store, and dissect the information. Cybersecurity and cloud computing helps oversee just two dangers of the project - information security, and information misfortune. It additionally has shortcomings, for example, loss of control, insider burglary, and unbound application programming interface. IoT has issues identified with security and protection of information. IoT builds up an assorted system to interface different gadgets, and a solitary escape clause can influence the whole framework.

Table 5 presents the risks of implementing Industry 4.0 technologies for managing projects in the construction sector. Irrespective of the sector, if project features are similar to those of the construction project, then with an increase in complexity levels and deadlines, resource and outsourcing risks become significant due to people loss, inadequate funds, and contract-related problems. If the project attributes are similar to the project discussed, which are of lower novelty and high complexity, irrespective of the pace (time-critical/fast competitive), delay risks are usually high due to external vendor problems, delay in parts, and incorrect estimations. Therefore, high-tech and high-complexity projects are highly susceptible to resource risks alone. Cybersecurity & data privacy risk has a significant impact on projects at a high-tech level. In projects with characteristics of the project discussed, fraud risk has a prominent impact on the success rate of the project. In conclusion, projects with high-tech, low in novelty, highly-complex are vulnerable to resource, outsourcing, and delay risks irrespective of pace.

4. Conclusion

The aim of this study was to analyse the role of Industry 4.0 in project management. To accomplish this, a case study involving a live project in the construction sector was discussed. The analyses helped in identifying that in projects characterised as derivative, low-tech, array and fast-competitive pace as per NTCP framework, outsourcing, resource, legal and regulation, cybersecurity, and delay risks are more prominent than other risks because of delayed outsourcing, likelihood of hacking of the centralised server and stringent guidelines of legal authorities. The analyses further affirm that these risks can be monitored and governed by using Industry 4.0 technologies while managing the project, which can increase the success rate of the project. Outsourcing and operational risks can be reduced with the help of blockchain technology, which increases transparency, efficiency, and speed. AR can be used to decrease delay risks by providing professional training and avoiding rework. To reduce hardware infrastructure risks, IoT can be used for the application of preventive maintenance. With the help of big data and cloud computing, cybersecurity and tech infrastructure risks can be significantly reduced. By comparing the PI matrices, we can conclude that with the application of Industry 4.0 technologies, outsourcing, cybersecurity, delay, resource, operational, fraud, regulatory, and hardware infrastructure risks can be significantly monitored to increase the success rate of the project.

The limitations of this research are only one project was analysed and the lack of actual implementation of recommendations due to project-specific constraints. Further research is highly recommended to validate the outcomes of this study in other sectors.

References

Ahmed, S., Hossain, M. and Hoque, I., “A brief discussion on augmented reality and virtual reality in construction industry”, *Journal of System and Management Sciences*, vol. 7, no. 3, pp. 1-33, 2017.

Azuma, R., "Overview of Augmented Reality." *Conference on SIGGRAPH 2004 Course Notes - GRAPH 04*, 2004.

Carmigniani, J., Borko, F., Marco, A., Paolo, C., Ernesto, D., and Misa, I., "Augmented Reality Technologies, Systems and Applications." *Multimedia Tools and* Applications, vol. 51, no. 1, pp. 77-341, 2010.

Chen, M., Shiwen, M., and Yunhao ,L., "Big Data: A Survey." Mobile Networks and Applications, vol. 19, no. 2, pp. 171-209, 2014.

Dillon, T., Wu, C., and Chang, E., Cloud Computing: Issues and Challenges, *2010 24th IEEE International Conference on Advanced Information Networking and Applications*. 2010

Heiser, J. and Nicolett, M., Assessing the Security Risks of Cloud Computing, Gartner Research, Stamford, CT, available at: http://cloud.ctrls.in/files/assessing-the-security-risks.pdf (accessed February 13, 2012), 2008.

Henderson, R. and Clark, K., Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms, *Administrative Science Quarterly*, vol. 35, no. 1, Special Issue: Technology, Organizations, and Innovation. pp. 9-30, 1990.

Liu, Y., Xi, D., Li, Z., and Shi, C., Analysis and Application of the Relationship between Cumulonimbus (Cb) Cloud Features and Precipitation Based on FY-2C Image. Atmosphere, vol. 5(2), pp. 211-229, 2014.

Rabechini, R., and Carvalho, M., "Understanding the Impact of Project Risk Management on Project Performance: an Empirical Study", *Journal of Technology Management and Innovation*, 2013.

Rane, S., Potdar, P. and Rane, S., Development of Project Risk Management framework based on Industry 4.0 technologies, *Benchmarking: An International Journal*, vol. ahead-of-print, no. ahead-of-print, 2019.

Rodrigues-Da-Silva, L. H., and Crispim, J. A., The Project Risk Management Process, a Preliminary Study. *Procedia Technology,* vol. 16, pp. 943-949, 2014.

Shenhar, A.J., "From low-to high-tech project management", *R&D Management*, vol. 23, no. 3, pp. 199-214, 1993.

Shenhar, A.J. and Dvir, D., "Toward a typological theory of project management", *Research Policy*, vol. 25, no. 4, pp. 607-632, 1996.

Shenhar, A.J. and Dvir, D., *Reinventing Project Management: The Diamond Approach to Successful Growth and Innovation,* Harvard Business Review Press, Boston, MA, 2007.

Shishodia, A., Dixit, V., and Verma, P., "Project risk analysis based on project characteristics", Benchmarking: An International Journal, Vol. 25 Issue: 3, pp.893-918, 2018.

Sinanc, D., and Sagiroglu, S., A review on cloud security, *Proceedings of the 6th International Conference on Security of Information and Networks - SIN 13*, 2013

Sveistrup, H., Motor rehabilitation using Rirtual Reality, Journal of Neuro Engineering and Rehabilitation, vol. 1(1), pp. 10., 2004.

Trappey, A.J.C., Trappey, C.V., Fan, C.-Y., Hsu, A.P.T., Li, X.-K. and Lee, I.J.Y., "IoT patent roadmap for smart logistic service provision in the context of Industry 4.0", *Journal of the Chinese Institute of Engineers*, vol. 40, no. 7, pp. 593-602, 2017.

Turner, J.R. and Cochrane, R.A., "Goals-and-methods matrix: coping with projects with ill-defined goals and/or methods of achieving them", *International Journal of Project Management*, vol. 11, no. 2, pp. 93-102, 1993.

Ward, B.T. and Sipior, J.C., "The internet jurisdiction risk of cloud computing", *Information Systems Management*, vol. 27, no. 4, pp. 334-339, 2010.

Win, T., Saing, N., and Kham, M., Transformation of Project Management in Industry 4.0, *12th International Conference on Project Management,* 2018.

Xin, W., Man, J., Zuowan, Z., Jihua, G., and David, H., 3D Printing of Polymer Matrix Composites: A Review and Prospective, *Composites Part B: Engineering*, 2016.

Biographies

Priyanka Verma is an Assistant Professor in Industrial Engineering and manufacturing systems (IEMS) at NITIE, Mumbai. Prof Priyanka has published her research work in the international and national journals of repute viz. International Journal of Production Research, Computers and Industrial Engineering, International Journal of Production Economics. Her research interest includes Operation Research and Supply Chain Modeling, Large-scale Optimization, Quantitative Modeling in Facility Locations, and Manufacturing Systems.

Vijaya Dixit is an Assistant Professor at Indian Institute of Management, Ranchi. She completed her Fellowship from the Indian Institute of Management Lucknow and graduated from Marine Engineering and Research Institute, Kolkata. After that, she worked for 2.5 years in the shipbuilding industry. Her research focus lies on the improvement of the performance of shipbuilding projects, which has resulted in publications in the International Journal of Production Research, Computers and Industrial Engineering, International Journal of Production Economics. She was conferred Young Research Scholar Award by Project Management Institute of India.

Miral Parikh is a student of Post Graduate Diploma in Industrial Management at NITIE - National Institute of Technology, Mumbai, India. He earned B.Tech. in Mechanical Engineering from Sardar Patel College of Engineering, Mumbai, India, in 2015. He has three years of experience working as a piping engineer and analytics associate in consulting companies.