Managing Risks Related to the Adoption of New Technologies by Various Stakeholders in Indian Construction Sector

Divya Negi, Deepak Bajaj, and Anil Sawhney

1 Introduction

The Indian construction sector is struggling with slight underperformance toward achieving equilibrium between four key elements, i.e., time, money, quality, and end-user satisfaction. The main reason behind not being able to do so is the amount of risk which usually arises knowingly or unknowingly to almost any construction project disrupting a great deal of efforts and resources. For decades the practice of risk management in construction projects has been subjective to phases of identification, analysis, mitigation, and control which are followed more or less in a similar order [14]. Undoubtedly, the process has continued to lead good results in effectively managing risks in small-scale projects and multi-scale industrial projects equally but since every construction project is distinct to one another and require different approach to address and treat their risks, the strategies which were developed earlier got tremendously evolved in due course of time.

Risk as a basic concept is slowly being understood by many and has taken a step forward toward updating themselves, keeping regular checks on what can possibly go wrong and has gone wrong in their projects. However, this is still not true for small players of Tier II and III cities and towns. Bigger engineering, procurement, and construction (EPC) companies in the country are mostly engaged in fully-fledged risk management. Their planning, activities, and tasks are made future-proof by either implementing innovative strategies or by introducing new technologies into their systems. The overall success of their projects lies in either or both being incorporated

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successfully by their team and managers. After the year 2020, the entire sector witnessed a moral obligation to transform and today incorporating new technologies in construction projects and firms is considered to be one of the best ways among all the strategies which is propagating at a very fast rate from companies to companies and professionals to individuals [15].

1.1 The Global Concept of Industry 4.0 in Construction Sector

The growth of industries together has lead to a complete revolution and this should clearly be credited to advancement in research and innovation. “From the technical point of view, Industry 4.0 can be described as the increasing digitization and automation of the manufacturing environment as well as the creation of a digital value chain to enable the communication between products and their environment and business partners. As a result, simultaneous planning of products and production processes leads to improvements in product quality and decrease time-to-market” [13]. The global concept of Industry 4.0 emerged in Indian construction sector as well and is talked through but seems still far from practicality as there are several risk factors attached to it.

2 The Purpose of the Study

With the growing focus on construction sector, reducing the susceptibility of the industry to equally enlarged and varied risks of today’s world is a huge challenge in itself. It is critical for executives to predict and judge to what the future will hold for them in terms of profits, changes in scenarios, business models, or in the entire business framework. The purpose of this study is to determine the present state of technology adoption in organizations and also to identify the key risk factors affecting the adoption by performing an analysis of the technology adoption risk factors.

Based on previous studies the possible challenges for construction industry in terms of technologies are listed below [13, 17]:

- Willingness to adopt a new technology: This could be either due to high initial investment costs and maintenance costs or non-clarity on its benefits
- High implementation costs: This is due to costs on associated peripherals, IT facilities, training and education, external consultation fees, etc.
- Organizational and process changes: Due to implementation of a disruptive technology the business models and processes change significantly and thus it becomes difficult to re-evaluate and re-design at different levels

- Need for hiring skilled professionals: New technology requires specific skill and knowledge and creating a pool of workforce of the right competencies is a great challenge for construction sector
- Knowledge management: Lack of codified and shared project knowledge makes it tough to automate data management, handling enormous data without monitoring and verification restricts the use of technology
- Lack of reference, standards, and architecture: There exists a lack of standards, references, and certifications when it comes to new technology. There is a need for an industry-specific reference architecture and increased participation, collaboration, and accreditation from the government.
- Acceptance: The construction industry's conservatism, strong sense of ownership, resistance to change and not reaching toward a common consensus make it nearly impossible for new technology to infiltrate the system.
- Higher requirements for computing equipments and facilities: High-end technology requires more advanced computing devices and allied facilities which are usually low in portability and flexibility to carry from one point to another on sites. The safety, accessibility, and availability of counterparts possess another challenge
- Data security and data protection: Due to increased volumes of data, information sharing, and mobility it has become a very essential for companies to protect their sensitive data and maintain privacy from fraudulent on servers and clouds
- Enhancement of existing communication networks: Accesses to fast and reliable internet in isolated locations makes it difficult to use equipments, sensors, and mobile devices
- Legal and contractual uncertainty and regulatory compliance: Another barrier is the concern over legality, responsibility, and compliance related to the usability of new technologies
- Fear of heavy lay-offs due to smart processes of new technologies
- Increased protection of sensitive devices from dust and pollutants present on-site
- Need to establish research and development facilities for better results in innovations
- Need to ensure proper monitoring, inspection, and validation of technologies and services.

2.1 Technology Areas

The primary focus of almost all industries is to prioritize their need for adopting a suitable technology based on certain justified reasons and conditions. For say, there could be some motivating factors for the contractors, developers, consultants, or any other related professional that encourage them to assess their options and survey through the technology market so as to reach a conclusion and decide on whether to take trials and safely invest or completely abandon the idea. These reasons may range between earning more profits, growing businesses, competing among competitors, increasing speed, accuracy, and quality of projects, gaining trust and maintaining transparency of processes, increasing risk appetite, effectively managing and monitoring different projects at the same time, enhancing value chain, become more inclusive and become environmentally sustainable for future. Depending upon such reasons and purposes the demand for technology adoption varies and similarly the notion of being ‘new’ to a technology from company to company also varies. The technology that is current or is available in the latest versions can also be considered as new, and a technology which was never used earlier from the perspective of the user can also be termed as new. Therefore, we can say that being ‘new’ is a relative term for technologies and it is irrespective of the time frame.

In order to summarize key technologies which have found their purpose in the construction industry Table 1 is developed showcasing systematic differentiation of fundamental disciplines/sciences and technologies under interdisciplinary, evolving, and advanced level areas (in short Technology Areas), where the latter shares the common roots of origins from the previous. These technology areas are realms of various sets of methods, systems, processes, and devices which may be categorized based on their application, capability, utility, functionality, current state of development, and scientific knowledge domain. Also, there exists an ever-growing list of technologies that are deemed fit into the Technology Areas of Future where the research and development is still underway.

3 Literature Review

There are many studies existing related to new technologies who have shaped the face of Indian construction sector, including those of current technological trends and evolution of Industry 3.0 to 4.0. For example, Ribeirinho et al. [15], [6] [4, 17, 16] have indicated several positive signs on a transformation and digitalization of the industry as a whole. The list of possible disruptive technologies has been shared along with their likely benefits and deliverables. Even authors have tried to address the problems and issues faced by companies and stakeholders while making firm decisions on adoption and implementation of these technologies into their projects and systems, such as [1, 12] for BIM-related adoption challenges in India, [5] for the perceptions on drones being adopted in Indian construction projects, and [2] tells exactly how 3D printing was welcomed for experimentation but still is far from its absorption on the field. Also there are unlimited literatures on application of new technologies in a mixed form to achieve targets in a project, for example [19, 18] stated that using a combination of building information modeling BIM (4D, 5D), virtual and augmented reality, Internet of Things, teleoperation, soft skills, artificial intelligence applied to big data and cybersecurity to manage risks related to occupational safety and health on construction sites. Further Basir et al. [3, 20] devised solution of integrating BIM and GIS in order to improve the entire life cycle of the construction project.

Table 1 List* of fundamental disciplines/sciences and technology areas

S. no	Fundamental discipline/science (generic)	S. no.	Technology areas (in context with construction sector)
1	*Engineering*:	1	*Evolved technology areas*:
1.1	Information and communication	1.1	Architecture and interior design
1.2	Construction	1.2	Cloud computing and storage
1.3	Electronics	1.3	Construction capital, funding, and investment
1.4	Mechanical	1.4	(FinTech)
1.5	Electrical	1.5	Data analytics
1.6	Design	1.6	Digital assessment and training
		1.7	Digital payments and banking
		1.8	Earthquake resistant technology
		1.9	Industrial manufacturing and production
		1.10	Facility management
		1.11	Financial data analytics and reporting
		1.12	Planning, scheduling, and management tools
			Mobile communication and devices
2	*Applied sciences*:	2	*Interdisciplinary technology areas*:
2.1	Computer science	2.1	Augmented and virtual reality
2.2	Data science	2.2	Assistive performance technology
2.3	Energy science	2.3	Enterprise resource planning (ERP)
2.4	Environment science	2.4	Green and clean technology
2.5	Geology and geomorphology	2.5	Construction biochemical technology
2.6	Material science	2.6	Internet of Things (IoT)
2.7	Medical science—ergonomics	2.7	Simulation
		2.8	Smart operative systems
		2.9	Transportation technology and logistics
		2.10	Robotics and automation
		2.11	Network and data security
		2.12	Underground and underwater construction Technology
3	Applied Mathematics	3	*Advanced technology areas*:
4	Management	3.1	Advance construction technology
5	Banking and Finance	3.2	Advance construction materials
6	Law	3.3	Building information modeling
7	Market and sales	3.4	Business intelligence and risk management
8	Education and Research	3.5	Distributed ledger technology (blockchain)
		3.6	Enterprise regulatory technology
		3.7	Geographical information system (GIS)
		3.8	Rapid prototyping technology
		3.9	Robotic process automation
		3.10	SCADA technology

(continued)

Table 1 (continued)

S. no	Fundamental discipline/science (generic)	S. no.	Technology areas (in context with construction sector)
		4 4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8	*Future technology areas*: Artificial intelligence Cloud banking technology Digital twin technology Internet of everything (IoE) Immersive reality and display Lean manufacturing Supply chain technology Smart materials

**Note* the above list is not exhaustive in terms of technologies available for construction sector
Source Author's/author's computation

So far, the literatures are exploratory when it comes to building a technique that can measure the intensity of risk exposure on construction projects. Few authors suggested a method of combining work breakdown structure and simultaneously its risk breakdown structure in the form of a two-dimensional matrix. [7] was the first literature who explain about risk breakdown matrix and how to use it for managing risks which includes numerous parameters. Several others build upon this taking their cases such as [9, 11, 10] WBS-RBS on EPC projects and for bridge construction and identifying hierarchy of fatal incidents on site.

4 Methodology

Although many literatures suggested the possible use of risk breakdown matrix (RBM) for a combination of work packages of construction projects (at y-axis) and risk breakdown structure (at x-axis) of the same [7], but there is no literature that suggests how to measure the overall risk exposure of projects by a new technology adoption. Therefore, in order to analyze quantitatively this contemporary structure a proposed version of RBM is introduced to systematically analyze the required parameters, where a modified risk breakdown matrix is constructed for a combination of technology areas (at y-axis) and risks of technology adoption (at x-axis) for all types of construction projects. A risk matrix [8] is also constructed for the likelihood of technology adoption against the impact of its adoption.

For better understanding of the modified RBM, the following Table 2 may be referred. The nomenclature given for project risk sources is RS1-15 and technology areas is TA1-15.

Under this matrix, every individual cell represents two values *Pi, n* and *Im, j* where *P* stands for probability of occurrence of technology adoption risk in the project and *I* stands for impact of adoption of that technology area (TA) on the project. The general formula for obtaining degree of criticality $(R)^{TA}$ is given by;

Table 2 Sample modified risk breakdown matrix for measuring risk exposure

Risk breakdown matrix												
			Risk breakdown structure									Values for TA
			Project risk sources									
			Task									
			RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8	RS9	
			Pi, 1	Pi,2	Pi, 3	Pi, 4	Pi, 5	Pi, 6	Pi, 7	Pi, 8	… Pi, n	ΣR i, j
Technology under the areas	TA1	I1, j										
	TA2	I2, j										
	TA3	I3, j				P 4,3 × I 3,4						
	TA4	I 4, j										
	TA5	I5, j										
	TA6	I6, j										
	TA7	I7, j										
	TA8	I8, j										
	TA9	I9, j										
	TA10	I10, j										
	TA11	I11, j										
	TA12	I12, j										
	TA13	I13, j										
	TA14	I14, j										
	TA15	…Im, j										
Risk sources evaluation		ΣR i, j										

Source Hillson, D., Grimaldi, S., and Rafele, C. (2006). Managing Project Risks Using a Cross Risk Breakdown Matrix. *Risk Management*, *8*(1), 61–76. https://doi.org/10.1057/palgrave.rm.825000

$$(R)^{TA}, i = \sum_{j=1}^{n} Pi, j * Ii, j \tag{1}$$

where $(R)^{TA}$, *i* is the global incidence of risks in *TA i; P i, j* is the probability of occurrence of risk-j in *TA*-*i*; *I i, j* is the impact of risk-j in *TA*-*i.*

Similarly, the sum of the values for each column identifies the relationship of all TAs of the project to a particular source of risk (RS) or the presence of risks in different TAs. The general formula is given by;

$$(R)^{RS}, j = \sum_{i=1}^{n} Pi, j * Ii, j \tag{2}$$

where $(R)^{RS}, j$ is the total effect of risk source risk-j in the whole project. The value obtained by summing columns using the second formula allows a classification of sources of technology adoption risks in terms of their influence on the project [7].

From both the Eqs. (1) and (2), the risk probability number (RPN) and probability number (PN) are calculated on each axis.

4.1 Data Collection

To gather values of probabilities and impact factors for each technology and associated risk, a detailed structured questionnaire was prepared on Google forms using Likert scale (low, medium, high and yes, no, maybe) and was sent to nearly 90 professionals working on construction projects in India out of which 40 responses were found to be appropriate for the analysis. Also, a telephonic survey was taken from 7 respondents who preferred guided filling of the same Google survey form for more clarity on thoughts.

5 Result

Each response of this pilot survey was translated into a formulation of a modified risk breakdown matrix, where a randomly selected response is represented as a sample analysis matrix in Table 3.

In the modified RBM, the risk source order shows risk probability number (RPN) obtained by $(R)^{RS}, 1, (R)^{RS}, 9,$ and $(R)^{RS}, 2$ to be of the value 1, 2, and 3, respectively. These ranks clearly outline the importance of such technology adoption risks having the potential to significantly affect a project's growth. The technology area order shows probability number (PN) of $(R)^{TA}, 17, (R)^{TA}, 20,$ and $(R)^{TA}, 6$ of values 1, 2, and 3, respectively [9]. And these ranks list down the technology areas which are least likely to be adopted newly to a construction project because of their higher impacts than others. Therefore, the technologies like Rapid Prototyping Technology (includes additive/subtractive manufacturing and 3D concrete printing), Artificial Intelligence, and Building Information Modeling are perceived as the top three most challenging new technologies to be adopted by any stakeholder for their projects of any scale in India. And having said that should definitely not be understood as adoption of these are not likely to happen in future. They will be adopted sooner or later. Further, the top three reasons and challenges came out to be initial investment and maintenance costs, hiring of qualified and subject-related professionals especially at the ground level, and the need to establish a strong information collection, distribution, use, and management mechanism in organizations hindering them for not getting picked up so fast in the construction sector. Also, the bottom four least risky technologies, having risk probability number (RPN = 22), are mobile communication devices and applications, smart personal protection equipments and suits (including wearables

Table 3 Modified risk breakdown matrix developed from responses of a respondent

Risk breakdown matrix									
				Risk breakdown structure					
				Project risk sources					
				RS1	RS2	RS3	RS4	RS5	RS6
				initial investment and maintenance costs	hiring qualified and subject relevent professionals, especially at the ground level	attitude towards learning new technological concepts	heavy lay-offs due to smart processes of new technologies	safety issues arising due to manhandling of systems and devices	need to establish a strong information collection, distribution, use, and management mechanism
				Pi, 1	Pi,2	Pi, 3	Pi, 4	Pi, 5	Pi, 6
	TA1	Basic and specialized softwares and tools	I1, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 3, I = 1	P = 2, I = 2
Technology under the areas	TA2	Smart PPE and exoskeleton suits	I2, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA3	Mobile communication devices and applications	I3, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA4	Data analytics tools and reporting	I 4, j	P = 3, I = 2	P = 3, I = 2	P = 1, I = 1	P = 3, I = 3	P = 1, I = 1	P = 2, I = 1
	TA5	Cloud computing and storage	I5, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	P = 3, I = 2	P = 1, I = 1	P = 1, I = 1

(continued)

Table 3 (continued)

Risk breakdown matrix										
				Risk breakdown structure						
				Project risk sources						
	TA6	Building information modelling	I6, j	P = 3, I = 3	P = 3, I = 3	P = 1, I = 1	P = 3, I = 3	P = 1, I = 1	P = 3, I = 3
	TA7	IoT tools	I7, j	P = 3, I = 2	P = 3, I = 2	P = 1, I = 1	P = 2, I = 2	P = 1, I = 1	P = 3, I = 2
	TA8	Simulation tools	I8, j	P = 3, I = 1	P = 3, I = 2	P = 1, I = 1	P = 2, I = 1	P = 1, I = 1	P = 3, I = 1
	TA9	Augmented and virtual reality tools	I9, j	P = 3, I = 3	P = 3, I = 3	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 2, I = 2
	TA10	Network and data security services and tools	I10, j	P = 3, I = 3	P = 3, I = 2	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 2, I = 2
	TA11	Interior design and decoration tools	I11, j	P = 3, I = 1	P = 3, I = 3	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA12	GIS (geographical information system), satellite navigation and mapping tools	I12, j	P = 3, I = 2	P = 3, I = 2	P = 1, I = 1	P = 2, I = 1	P = 1, I = 1	P = 2, I = 2
	TA13	Database management system (DBMS) and frameworks	I13, j	P = 3, I = 3	P = 3, I = 1	P = 1, I = 1	P = 2, I = 2	P = 1, I = 1	P = 2, I = 2
	TA14	Customer relationship management (CRM) tools	I14, j	P = 3, I = 3	P = 3, I = 2	P = 1, I = 1	P = 2, I = 2	P = 1, I = 1	P = 2, I = 2

(continued)

Table 3 (continued)

Risk breakdown matrix									
				Risk breakdown structure					
				Project risk sources					
	TA15	Enterprise resource planning (ERP) tools	I15, j	P = 2, I = 2	P = 3, I = 2	P = 1, I = 1	P = 2, I = 2	P = 1, I = 1	P = 2, I = 1
	TA16	Green technology	I16, j	P = 2, I = 2	P = 2, I = 2	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA17	Rapid prototyping technology	I17, j	P = 3, I = 3	P = 3, I = 2	P = 1, I = 1	P = 3, I = 3	P = 1, I = 1	P = 3, I = 3
	TA18	Construction biochemical technology	I18, j	P = 2, I = 2	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA19	Earthquake and seismic technology	I19, j	P = 3, I = 3	P = 2, I = 2	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA20	Artificial intelligence	I20, j	P = 3, I = 3	P = 3, I = 3	P = 1, I = 1	P = 3, I = 3	P = 1, I = 1	P = 1, I = 1
	TA21	Offsite manufacturing	I21, j	P = 3, I = 3	P = 3, I = 3	P = 1, I = 1	P = 3, I = 2	P = 3, I = 1	P = 1, I = 1
	TA22	Education and training tools	I22, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA23	SCADA	I23, j	P = 3, I = 3	P = 2, I = 2	P = 1, I = 1	P = 3, I = 2	P = 3, I = 1	P = 3, I = 3
	TA24	Robotics and automation	I24, j	P = 3, I = 2	P = 2, I = 1	P = 1, I = 1	P = 3, I = 3	P = 3, I = 1	P = 2, I = 1
	TA25	Smart operative systems	I25, j	P = 3, I = 2	P = 2, I = 1	P = 1, I = 1	P = 2, I = 1	P = 3, I = 1	P = 2, I = 1

(continued)

Table 3 (continued)

Risk breakdown matrix									
				Risk breakdown structure					
				Project risk sources					
	TA26	Multifunctional machines and equipments	I26, j	P = 3, I = 1	P = 2, I = 1	P = 1, I = 1	P = 2, I = 1	P = 3, I = 1	P = 1, I = 1
	TA27	Advance surveying technology	I27, j	P = 3, I = 3	P = 2, I = 2	P = 1, I = 1	P = 1, I = 1	P = 3, I = 1	P = 1, I = 1
	TA28	Robotic process automation	I28, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	P = 3, I = 1	P = 1, I = 1	P = 3, I = 2
	TA29	Distributed ledger technology (blockchain)	I29, j	P = 3, I = 1	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 2, I = 2
	TA30	Enterprise regulatory technology	I30, j	P = 3, I = 1	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 3, I = 2
	TA31	Logistics and transportation technology	I31, j	P = 3, I = 1	P = 2, I = 2	P = 1, I = 1	P = 2, I = 1	P = 1, I = 1	P = 2, I = 2
	TA32	Digital payments and banking tools	I32, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA33	Modern formwork systems	I33, j	P = 3, I = 2	P = 3, I = 2	P = 1, I = 1	P = 1, I = 1	P = 3, I = 1	P = 1, I = 1

(continued)

Table 3 (continued)

	Risk sources evaluation			171	130	33	107	49	102
	Risk sources order			1	3	13	5	10	6
				RS7	RS8	RS9	RS10	RS11	RS12
				increased protection of sensitive devices from dust and pollutants present on-site	providing contractors and sub-contractors the necessary skills and understanding of the processes	need to ensure proper monitoring, inspection, and validation of services	Lack of regulation, standards, and certifications	getting a common consensus on the adoption from the employees and management	need to establish research and development facilities
				Pi, 7	Pi, 8	Pi, 9	Pi, 10	Pi, 11	Pi, 12
Technology under the areas	TA1	Basic and specialized softwares and tools	I1, j	P = 1, I = 1	P = 1, I = 1	P = 2, I = 2	P = 2, I = 2	P = 1, I = 1	P = 1, I = 1
	TA2	Smart PPE and exoskeleton suits	I2, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA3	Mobile communication devices and applications	I3, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA4	Data analytics tools and reporting	I 4, j	P = 1, I = 1	P = 1, I = 1	P = 2, I = 2	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1
	TA5	Cloud computing and storage	I5, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1
	TA6	Building information modelling	I6, j	P = 1, I = 1	P = 2, I = 1	P = 3, I = 3	P = 2, I = 1	P = 1, I = 1	P = 2, I = 1

(continued)

Table 3 (continued)

	Risk sources evaluation			171	130	33	107	49	102
	Risk sources order			1	3	13	5	10	6
	TA7	IoT tools	I7, j	P = 1, I = 1	P = 2, I = 1	P = 3, I = 2	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1
	TA8	Simulation tools	I8, j	P = 1, I = 1	P = 2, I = 1	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA9	Augmented and virtual reality tools	I9, j	P = 1, I = 1	P = 2, I = 1	P = 2, I = 2	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1
	TA10	Network and data security services and tools	I10, j	P = 1, I = 1	P = 1, I = 1	P = 3, I = 2	P = 3, I = 3	P = 1, I = 1	P = 1, I = 1
	TA11	Interior design and decoration tools	I11, j	P = 1, I = 1	P = 1, I = 1	P = 2, I = 2	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA12	GIS (geographical information system), satellite navigation and mapping tools	I12, j	P = 1, I = 1	P = 1, I = 1	P = 3, I = 3	P = 3, I = 3	P = 1, I = 1	P = 1, I = 1
	TA13	Database management system (DBMS) and frameworks	I13, j	P = 1, I = 1	P = 1, I = 1	P = 3, I = 3	P = 3, I = 2	P = 1, I = 1	P = 1, I = 1
	TA14	Customer relationship management (CRM) tools	I14, j	P = 1, I = 1	P = 1, I = 1	P = 3, I = 2	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1

(continued)

Table 3 (continued)

	Risk sources evaluation			171	130	33	107	49	102
	Risk sources order			1	3	13	5	10	6
	TA15	Enterprise resource planning (ERP) tools	I15, j	P = 1, I = 1	P = 1, I = 1	P = 3, I = 2	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1
	TA16	Green technology	I16, j	P = 1, I = 1	P = 2, I = 2	P = 2, I = 1	P = 2, I = 2	P = 1, I = 1	P = 2, I = 1
	TA17	Rapid prototyping technology	I17, j	P = 1, I = 1	P = 1, I = 1	P = 3, I = 3	P = 3, I = 3	P = 1, I = 1	P = 2, I = 1
	TA18	Construction biochemical technology	I18, j	P = 1, I = 1	P = 1, I = 1	P = 2, I = 2	P = 3, I = 3	P = 1, I = 1	P = 2, I = 1
	TA19	Earthquake and seismic technology	I19, j	P = 1, I = 1	P = 1, I = 1	P = 3, I = 2	P = 3, I = 3	P = 1, I = 1	P = 1, I = 1
	TA20	Artificial intelligence	I20, j	P = 1, I = 1	P = 1, I = 1	P = 2, I = 1	P = 3, I = 2	P = 1, I = 1	P = 1, I = 1
	TA21	Offsite manufacturing	I21, j	P = 1, I = 1	P = 1, I = 1	P = 3, I = 3	P = 3, I = 2	P = 1, I = 1	P = 1, I = 1
	TA22	Education and training tools	I22, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA23	SCADA	I23, j	P = 1, I = 1	P = 2, I = 1	P = 2, I = 2	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1
	TA24	Robotics and automation	I24, j	P = 1, I = 1	P = 2, I = 1	P = 2, I = 1	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1
	TA25	Smart operative systems	I25, j	P = 1, I = 1	P = 2, I = 1	P = 1, I = 1	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1

(continued)

Table 3 (continued)

	Risk sources evaluation			171	130	33	107	49	102
	Risk sources order			1	3	13	5	10	6
	TA26	Multifunctional machines and equipments	I26, j	P = 1, I = 1	P = 2, I = 1	P = 2, I = 1	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1
	TA27	Advance surveying technology	I27, j	P = 1, I = 1	P = 2, I = 1	P = 3, I = 3	P = 3, I = 2	P = 1, I = 1	P = 1, I = 1
	TA28	Robotic process automation	I28, j	P = 1, I = 1	P = 2, I = 1	P = 1, I = 1	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1
	TA29	Distributed ledger technology (blockchain)	I29, j	P = 1, I = 1	P = 1, I = 1	P = 2, I = 1	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1
	TA30	Enterprise regulatory technology	I30, j	P = 1, I = 1	P = 2, I = 1	P = 2, I = 1	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1
	TA31	Logistics and transportation technology	I31, j	P = 1, I = 1	P = 2, I = 1	P = 2, I = 1	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1
	TA32	Digital payments and banking tools	I32, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1
	TA33	Modern formwork systems	I33, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1

(continued)

Table 3 (continued)

	Risk sources evaluation			33	43	133	121	33	37
	Risk sources order			13	11	2	4	13	12
				RS13	R14	RS15	Values for TA	TA Order	
				proper internet connectivity and other IT facilities and services	significant organizational and process change	govermental policy change and legalities			
				Pi, 13	Pi, 14	Pi, 15			
Technology under the areas	TA1	Basic and specialized softwares and tools	I1, j	P = 2, I = 2	P = 1, I = 1	P = 1, I = 1	31	17	
	TA2	Smart PPE and exoskeleton suits	I2, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	17	22	
	TA3	Mobile communication devices and applications	I3, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	17	22	
	TA4	Data analytics tools and reporting	I 4, j	P = 2, I = 1	P = 1, I = 1	P = 1, I = 1	39	15	
	TA5	Cloud computing and storage	I5, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	26	21	
	TA6	Building information modelling	I6, j	P = 3, I = 1	P = 2, I = 2	P = 1, I = 1	63	3	
	TA7	IoT tools	I7, j	P = 3, I = 1	P = 2, I = 1	P = 1, I = 1	43	11	
	TA8	Simulation tools	I8, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	30	18	
	TA9	Augmented and virtual reality tools	I9, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	41	13	
	TA10	Network and data security services and tools	I10, j	P = 3, I = 1	P = 1, I = 1	P = 2, I = 1	47	8	
	TA11	Interior design and decoration tools	I11, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	30	18	
	TA12	GIS (geographical information system), satellite navigation and mapping tools	I12, j	P = 3, I = 1	P = 2, I = 1	P = 2, I = 1	49	7	
	TA13	Database management system (DBMS) and frameworks	I13, j	P = 3, I = 1	P = 3, I = 2	P = 1, I = 1	46	9	
	TA14	Customer relationship management (CRM) tools	I14, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	42	12	
	TA15	Enterprise resource planning (ERP) tools	I15, j	P = 3, I = 1	P = 2, I = 1	P = 1, I = 1	36	16	

(continued)

Table 3 (continued)

	Risk sources evaluation			33	43	133	121	33	37
	Risk sources order			13	11	2	4	13	12
	TA16	Green technology	I16, j	P = 1, I = 1	P = 1, I = 1	P = 2, I = 1	30	18	
	TA17	Rapid prototyping technology	I17, j	P = 1, I = 1	P = 3, I = 3	P = 2, I = 1	70	1	
	TA18	Construction biochemical technology	I18, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	30	18	
	TA19	Earthquake and seismic technology	I19, j	P = 1, I = 1	P = 1, I = 1	P = 2, I = 1	40	14	
	TA20	Artificial intelligence	I20, j	P = 3, I = 1	P = 3, I = 3	P = 2, I = 1	65	2	
	TA21	Offsite manufacturing	I21, j	P = 1, I = 1	P = 1, I = 1	P = 2, I = 1	52	5	
	TA22	Education and training tools	I22, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	17	22	
	TA23	SCADA	I23, j	P = 3, I = 3	P = 2, I = 2	P = 1, I = 1	57	4	
	TA24	Robotics and automation	I24, j	P = 2, I = 2	P = 2, I = 2	P = 3, I = 3	50	6	
	TA25	Smart operative systems	I25, j	P = 3, I = 2	P = 2, I = 2	P = 2, I = 2	39	15	
	TA26	Multifunctional machines and equipments	I26, j	P = 2, I = 2	P = 1, I = 1	P = 1, I = 1	26	21	
	TA27	Advance surveying technology	I27, j	P = 2, I = 2	P = 1, I = 1	P = 1, I = 1	45	10	
	TA28	Robotic process automation	I28, j	P = 3, I = 1	P = 2, I = 1	P = 1, I = 1	30	18	
	TA29	Distributed ledger technology (blockchain)	I29, j	P = 3, I = 1	P = 1, I = 1	P = 2, I = 1	27	20	
	TA30	Enterprise regulatory technology	I30, j	P = 3, I = 1	P = 1, I = 1	P = 2, I = 1	30	18	
	TA31	Logistics and transportation technology	I31, j	P = 3, I = 1	P = 1, I = 1	P = 1, I = 1	29	19	
	TA32	Digital payments and banking tools	I32, j	P = 1, I = 1	P = 1, I = 1	P = 3, I = 1	17	22	
	TA33	Modern formwork systems	I33, j	P = 1, I = 1	P = 1, I = 1	P = 1, I = 1	27	20	
	Risk sources evaluation			94	69	55			
	Risk sources order			7	8	9			

Source Author's/Author's Computation

such as armbands, health trackers, smart helmets, goggles, gloves, safety harness, etc.), digital training and assessment tools, and digital payments and banking tools. The risk matrix is developed for all the 33 technology areas mentioned in Table 4 as per the same response received from the survey. It depicts the level of acceptance of technologies in the sector from his/her perspective, where Mobile Communication and Devices TA3, Augmented and Virtual Reality Tools TA9, Customer Relationship Management (CRM) Tools TA14, Green and Clean Technology TA16, Rapid Prototyping Technology TA17, Earthquake Resistant Technology TA19, Offsite Manufacturing TA21, Advance Surveying Tools TA27, and Digital Payments and Banking Tools TA32 are among the technologies having a greater chance of adoption (not in the same order of importance) regardless of the construction risks they are capable of managing in projects and organizations.

Similarly, the rest of the survey responses were analyzed and the technology area having the highest chances of being adopted is Mobile Communication and Devices TA3 (Total count = 39/40). This was simply derived based on the total number of counts appearing in either of the bottom three TA order ranks from each modified RBM. The highest chance of a technology area not being adopted came out to be SCADA TA23 (Total count = 2/40). The technology adoption risk factor being the highest is investment and maintenance cost R1 (Total count = 32/40), and the least is the increased protection of sensitive devices from dust and pollutants on site R7 (Total count = 6/40).

Table 4 Risk matrix of technology areas based on survey response

RISK matrix of technology area			
Likelyhood of being adopted	Impact of adoption on project		
	Low	Medium	High
Unlikely	TA1, TA4, TA5, TA6, TA7, TA8, TA10,TA11		TA30
	TA13, TA20, TA23, TA25, TA28, TA29, TA31		
Likely	TA12, TA15,	TA18, TA26,	TA2
	TA22, TA24	TA33	
Certain			TA3, TA9, TA14, TA16, TA17,
			TA19,TA21, TA27, TA32

Source Hussey, D. E. (1978). Portfolio analysis: Practical experience with the Directional Policy Matrix. *Long Range Planning*, *11*(4), 2–8. https://doi.org/10.1016/0024-6301(78)90001-8

6 Conclusion

It is unarguably the adoption risks of the technologies or technology areas which are dragging down the pace of the construction sector in India. Therefore, based on the above findings of the study it may be concluded that both the analysis techniques together can measure which type of new technology (or technology area) is being gravely affected by which type of adoption risk and thus influencing the overall likelihood of the adoption in projects from the viewpoint of the stakeholder. In other words, this pilot research study tried to reveal the present case scenario of the adoption of various new technologies in India.

7 Limitations and Future Scope of Study

The overall scope of this study is limited to when there is a need to gauge each technology area on the level of its complete potential vis-à-vis its exact utility as a risk factor for its adoption. Also, there was seen as an unquestionable relation between the technology adoption and the type of organizations, and type of project, such as residential, commercial, institutional, industrial, infrastructure, agriculture, etc., along with the scale of the organizations involved. The future progress in the study can be made by testing the feasibility of the analysis method for another set of adoption risks with some other set of new technologies or futuristic technologies. The data collection can also be further enhanced by introducing Delphi technique, personal interview, or any other suitable form of survey.

References

1. Ahuja R, Jain M, Sawhney A, Arif M (2016) Adoption of BIM by architectural firms in India: technology–organization–environment perspective. Archit Eng Des Manage 12(4):311–330. https://doi.org/10.1080/17452007.2016.1186589
2. Anjum T, Dongre P, Misbah F, Nanyam VPSN (2017) Purview of 3DP in the Indian built environment sector. Proc Eng 196(June):228–235. https://doi.org/10.1016/j.proeng.2017.07.194
3. Basir WNFWA, Majid Z, Ujang U, Chong A (2018) Integration of GIS and BIM techniques in construction project management—a review. Int Arch Photogram Rem Sens Spat Inf Sci ISPRS Arch 42(4/W9):307–316. https://doi.org/10.5194/isprs-archives-XLII-4-W9-307-2018
4. Benz SM (1997) The project manager's CADD survival guide. The Project Manager's CADD Survival Guide, May. https://doi.org/10.1061/9780784402474
5. Charlesraj VPC, Rakshith N (2020) Stakeholder perspectives on the adoption of drones in construction projects. In: Proceedings of the 37th international symposium on automation and robotics in construction, ISARC 2020: from demonstration to practical use—to new stage of construction robot, October, pp 1227–1234. https://doi.org/10.22260/isarc2020/0168
6. Digitalisation in construction report 2022 RESEARCH IP i Digitalisation in construction report 2022

7. Hillson D, Grimaldi S, Rafele C (2006) Managing project risks using a cross risk breakdown matrix. Risk Manage 8(1):61–76. https://doi.org/10.1057/palgrave.rm.8250004
8. Hussey DE (1978) Portfolio analysis: practical experience with the directional policy matrix. Long Range Plan 11(4):2–8. https://doi.org/10.1016/0024-6301(78)90001-8
9. Iranmanesh H, Jalili M, Pirmoradi Z (2007) Developing a new structure for determining time risk priority using risk breakdown matrix in EPC projects. In: IEEM 2007: 2007 IEEE international conference on industrial engineering and engineering management, 1, 999–1003. https://doi.org/10.1109/IEEM.2007.4419342
10. Jeong J, Jeong J (2021) Novel approach of the integrated work & risk breakdown structure for identifying the hierarchy of fatal incident in construction industry. J Build Eng 41:102406. https://doi.org/10.1016/j.jobe.2021.102406
11. Li QF, Zhang P, Fu YC (2013) Risk identification for the construction phases of the large bridge based on WBS-RBS. Res J Appl Sci Eng Technol 6(9):1523–1530. https://doi.org/10.19026/rjaset.6.3863
12. Mohanta A, Das S (2022) Causal analysis of slow BIM adoption in Eastern India with a special focus on green building sector. J Inst Eng (India) Ser A 103(1):319–337. https://doi.org/10.1007/s40030-021-00561-w
13. Oesterreich TD, Teuteberg F (2016) Understanding the implications of digitisation and automation in the context of Industry 4.0: a triangulation approach and elements of a research agenda for the construction industry. Comput Ind 83:121–139. https://doi.org/10.1016/j.compind.2016.09.006
14. Project Management Institute (nd) The standard for project management and a guide to the project management body of knowledge (PMBOK guide)
15. Ribeirinho MJ, Blanco JL, Mischke J, Rockhill D, Sjödin E, Strube G, Palter R, Andersson T (2020) The next normal in construction. Mckinsey & Company, p 84
16. Sawhney A, Riley M, Irizarry J, Pérez CT (2020) A proposed framework for Construction 4.0 based on a review of literature. 1, 301–291. https://doi.org/10.29007/4nk3
17. Singh A, Kumar V, Verma P, Kandasamy J (2022) Identification and severity assessment of challenges in the adoption of industry 4.0 in Indian construction industry. Asia Pac Manage Rev. https://doi.org/10.1016/j.apmrv.2022.10.007
18. Tender M, Couto JP (2022) Prevention of occupational risks in a construction site using BIM. In: Studies in systems, decision and control, vol 406. https://doi.org/10.1007/978-3-030-89617-1_6
19. Tender M, Couto JP, Gibb A, Fuller P, Yeomans S (2022) Emerging technologies for health, safety and well-being in construction industry. In: Structural integrity, vol. 20. https://doi.org/10.1007/978-3-030-82430-3_16
20. Wan Abdul Basir WNFA, Ujang U, Majid Z, Azri S, Choon TL (2020) The integration of bim and gis in construction project—a data consistency review. Int Arch Photogram Rem Sens Spat Inf Sci ISPRS Arch 44(4/W3):107–116. https://doi.org/10.5194/isprs-archives-XLIV-4-W3-2020-107-2020