



(RESEARCH ARTICLE)



Cross-disciplinary risk assessment models for integrated project delivery in large-scale civil engineering projects

Pratik Bhikhubhai Panchal *

Senior Scheduler Project Controls Specialist, Stantec Canada.

World Journal of Advanced Engineering Technology and Sciences, 2023, 08(01), 484-496

Publication history: Received on 22 December 2022; revised on 24 February 2023; accepted on 27 February 2023

Article DOI: <https://doi.org/10.30574/wjaets.2023.8.1.0041>

Abstract

Collaboration as a distinct activity exists across the planet only among a small number of actors because it requires deep diversity across long periods of definition while transcending traditional boundaries. The project actors unite continuously under integrated project delivery to work together from project start until completion through one unified delivery method. The concept applies to any moment starting from the beginning up to the end.

The research develops an analytical model to enhance current IPD risk evaluation systems by analyzing typical risk components needed for civil engineering projects. Organizations employed risk strategies across different disciplines to evaluate their response assessments via a framework which integrated technical systems with organizational structures and social elements according to recent research evaluations based on real case evidence.

Research uncovered essential differences between conventional models because these models did not have capability for observing disciplinary ties together with quick modifications to stakeholder operational mandates. The proposed framework succeeds in improving validity assessment of team risk communication processes while it develops resilient systems for better decision-making capabilities. The research adds value to ongoing talks about project delivery methods that investigate planning and project engineering and infrastructure project management association dynamics.

Keywords: Integrated Project Delivery (Ipd); Cross-Disciplinary Risk; Risk Assessment Models; Civil Engineering Projects; Large-Scale Infrastructure; Collaborative Project Management; Multidisciplinary Collaboration; Construction Risk Management; Project Delivery Frameworks

1. Introduction

Civil engineering mega projects are among the biggest and the most dramatic ventures in modern-day infrastructure concerning areas such as highways, rail networks, airport, bridges, and other complicated urban systems. The distinguishing characteristics typical of mega projects include their gigantic volume scale, amounts of investment, and prolonged engagement of various stakeholders. Eventually, the associating with mega ventures creates complexities related to technical and logistical constraints because of the contributions of inputs by disciplines into civil engineering, structural engineering, environmental engineering, architecture, urban planning, and project managing. Moreover, with indefinite extension of duration and the swaying factors of changing regulatory regimes, social consciousness, and environmentally friendly conscience, multidisciplinary interactions also become complicated; consequently, opening up huge opportunities for uncertainty and risk throughout the entire project development process-from inception to completion (Aktan et al. 2022).

* Corresponding author: Pratik Bhikhubhai Panchal.

As a result, it would be necessary for drastic change the project would take ages to do anything meaningfully different from separating an activity from integrated delivery through integrated project delivery (IPD). A life cycle so concerned goes on to become fully and intensely collaborative," which brings all relevant parties involved-the project owner, architect, engineer, contractor, consultants, and most other key participants-from conceptualization to execution and project transfer. Traditional models of delivery, wherein design responsibilities usually become separate from those for construction," statement given by Walker, Vaz Serra, and Love (2022). Such collaboration will drive joint accountability and decision-making continuously dialogue bringing together various expertise for better project performance and value-creation. Such IPD also embraces innovation and transparency which in turn creates a culture of constructive trust and decreased wastages with immediate alleviation of emerging operational challenges within projects but as Brncich et al. (2011) put it.

In fact, the magnificent accumulation of benefits accompanying IPD is eclipsed by the very vision of obstacles associated with gaining comparability in identification, analysis, and management of risks as they differ with various levels of collaboration across disciplines. Risk assessment traditionally flaunts its province all set up within its own lane-besides about a bit more than noisily residing with such items as being called financial forecasting, structural integrity, or legal compliance. However, integrated risks have not had much lively discussion around the pathways of IPD, actually were not likely to interface along lines that cross departments, such as architectural design and engineering viability; contractors and sustainability consultants. Cross-disciplinary risk cutting barrier would be a problem for nomenclature, values work culture, and adaptations for solving technical-human involving problems (Dewulf et al., 2007; Löfgren, 2020).

These present-day risk management frameworks ought to adapt to the small differences among them, and they mainly depend on linear processes and retrospective assessment. Therefore, we require a completely new type of risk model that would be a holistic, adaptive integration from several disciplines. Such models would require capacity for qualitative, quantitative, and socio-tech parameter information along with the ability to perform real-time processing to initiate early detection and avoidance of the risk. Besides, the evolution and use of transdisciplinary frameworks for risk assessments in IPD would critically contribute to making large civil engineering projects more reliable, effective, and successful. Given the inextricable intertwining of these project objectives, such strategies will also have to design-in sustainability and resilience much more closely than ever for each project.

1.1. Problem Statement

Integrative project delivery is the current trend in project development, whether one accepts it or not, by integrating all the engineering practices of the past to some degree, with a view to obtaining a higher percentage of obnoxious Ver gores closed opposed to any collegial approach with respect to stakeholders. Set the environment for collaboration through early engagement of all roles in fulfilling the requirements of the IPD project as much as possible in line with encouraging developing a sense of common ownership among parties with those shared objectives and mutual accountability by means of cooperativeness in bringing along the elements of decision making and administration. It is one, if not the most complex issue in the industry: Managing cross-disciplinary risks. The most common occurrence of cross-discipline risks is within or across architecture-structure-engineering-environment-shared project management areas; by less than commonly occurring cross-disciplinary risk, this refers to a fault in a single, isolated technical area. The widely publicized issue within integrated delivery, however, is that the assumptions, priorities, and even language may conflict and thus open doors for miscommunication and misalignment in such uneventful and unforeseen consequences.

In contrast, the traditional risk model allows presuming a project to have its duration traced in historical terms within interrelated chains of what are claimed to be linear events crossing between start and end. On the other hand, this specific risk is on a model that disregards that risk applicable to that single discipline alone. Some risks can reasonably be justified uniquely by that one discipline, while they share other common considerations with some resemblance to the risk related to the deliberation on risk management within that fair area of responsibility of the said discipline. Among the many disadvantages regarding their degree of inter-consultation and complexity cutting across various engineering domains is the collaborative integrated philosophy embraced by the IPD. Very few of the critical risks concerning different disciplines overlap.

Embedded within coordination problems between design teams and construction teams; poor communication between consultants and contractors; conflicting priorities between sustainability professionals and cost managers, among others, several risks are not considered until they become matters of serious discussion, such as injury to reputation, schedule delays, extra costs incurred, decline in design quality, and even sometimes failure in cooperation (Urton & Murray, 2021).

1.2. Objectives of the Study

The project investigation consists of three essential goals.

- The evaluation targets to determine main interprofessional risks that appear in large civil engineering work when implementing IPD approaches.
- All present risk evaluation systems require an assessment process to determine their capability in detecting threats between different professions.
- The proposed system merges IPD principle-based risk evaluation methods with proactive risk management abilities to perform interdisciplinary assessments.

1.3. Research Questions

The research aims to address three critical questions regarding this topic.

- Which risks do civil engineering teams encounter during large-scale IPD project delivery?
- What level of effectiveness does the present risk assessment methodology demonstrate in handling existing cross-disciplinary risks?
- To improve cross-disciplinary risk mitigation through existing models what specific innovative changes are possible for more efficient risk management?

1.4. Scope and Limitations

The research examines Project Implementation Development applications for large infrastructure through different geographical zones. The assessments examine both completed infrastructure projects and current developments that establish transportation infrastructure with additional building of urban infrastructure and community facilities. However, certain limitations are acknowledged:

- The study relies heavily on multiple project variables to establish results which are suitable for new site applications.
- The risk perception of stakeholders along with their participation levels exhibit geography-specific variations due to cultural norms and respective regulations and laws.
- The main focus of this research revolves around risk assessment as its central matter but fails to provide enough analysis for project governance alongside contractual particulars.

2. Literature review

2.1. Integrated Project Delivery (IPD): Concept and Principles

Delivering projects truly under public stand for an Integrated Project Delivery is progressive in time. Practically, the integrated project delivery implies here that an agreed process among parties in the contract covers every aspect from money-time to quality and sustainability-in what way everyone, every system, organization/business, architecture and practice would come together maximally for the end result of the project. These opposing philosophies that occupy the ends of basically one spectrum bring about oppositional outcomes toward dissimilar others; that is, design-bid-build, which majorly brings gaps in operational processes working on site without hindrance to already existing adjacent adversarial relationships among all stakeholders. The bones of IPD are transparency, mutual trust and collective accountability. It holds that if all major players-project owner, architects, engineers, contractors, and other stakeholders-enter the project early and maintain the same understanding of what the objectives of the project should be, they will facilitate alignment from as early as practicable (Walker et al. 2022).

However, paradigm shift-in terms of project governance, culture crucial of such actually picture events. These in turn ensure faith and comprehension to do away with inefficiencies normally associated with silo-type project implementers. The other part of evolution of IPD may as well be traced from that dawn of an industry when just the disadvantages of the conventional systems started to come out clearly; disadvantages all too punitive on contracts for large-scale and complex earthworks projects where collaboration among diverse disciplines and adaptability in management approaches would have to be given to meet conflicting requirements of the projects.

From that moment onwards, world project practice on IPD made it an imperative shift from a theoretical research land. Confirmatory and literal, the co-creating of energy among the team for the development of solutions for each and every one of the actors under common aligned goals minimizes the potential of conflict and rework on its own. If anything, in

fact, IPD refers to a method of good cost forecasting and efficiency in resource productivity, rather than necessarily fast-tracking schedules (Brncich et al., 2011). Now that cities have the growing demand for urban infrastructure, this is a big opening for IPD. That's why they are calling for assistance to establish IPD in civil engineering and urbanization (Aktan et al., 2022). So, beyond being a delivery mechanism, IPD is quite a strategic framework for manipulating complex systems through integrated thought and cooperation.

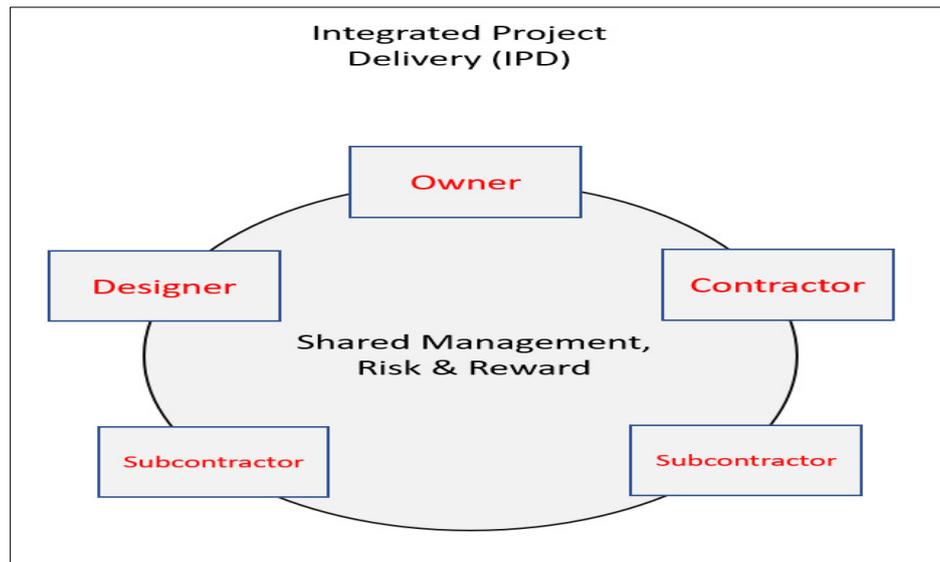


Figure 1 Introduction to Integrated Project Delivery

2.2. Risk Management in Construction Projects

The methodology of risk management in construction works involves bringing into existence almost all process plans that pertain to activities necessary for constructing a house and then identifying, assessing, and attempting to manage all risks foreseen in carrying out these activities right from initiation until completion during the life cycle of a project. Financial risk may probably be one aspect; for this, the hidden costs would be those that are above budget or involve the unavailability of funds; design, machinery, or the construction process not being able to come on time may oftentimes be termed as otherwise pertaining to technical risk. Legal risks are commonly the whole set of risks arising from classic scheme laws such as regulation or compliance, breach of contract, or variation due to change in random law put into effect in the course of the project; while environmental risks are those that can block or hinder the carrying out of construction activities either on account of naturally occurring phenomena or as impacted by climate change or some unforeseen human-induced environmental upheavals; prolonged periods of physical disturbance mostly caused by hindrance.

As such, risk management is the prime means to exploit benefits within uncertainties of construction works. These include FMEA, sensitivity analysis, Monte Carlo simulation, etc. Among these, FMEA stands out as an instrument that would work toward an optimum outcome related to some certainties to project-related possible failures and weigh these consequences against other causes of failures. In other words, sensitivity analysis goes in both ways in order to extract from a single scenario many outputs that may be influenced by only a handful of key input variables; Monte Carlo, on a grand scale, draw random samples to model such outputs probabilistically from statistical methods, thus making a good fortification for the horizon of the possible areas of risk involved, risk evaluation. With all the advances in metrology, the acceptance of Monte Carlo for risk evaluation and management has grown exponentially in construction works along project parameters with explicit quantification of uncertainty (Lisø, 2006).

The uncertainties probably come very much from method concerns, classify them into risk assessment methods applicable mainly in the case of very complicated inter-project environments. Most modes stress narrowly technical or purely financial dimensions, leaving almost painfully narrow stakes for risking considerations, for the most part, regarding risk specificity. An interdisciplinary outlook shows how interrelations of risks act synergistically to form vortexes; this adds real complexity to collaborative heavy construction projects, thus putting whole orbiting patterns into motion and even simultaneously connecting to build such vast risk orchestrator: a gaggle of professions-civil engineering, architects, construction management, contracting, and so forth.

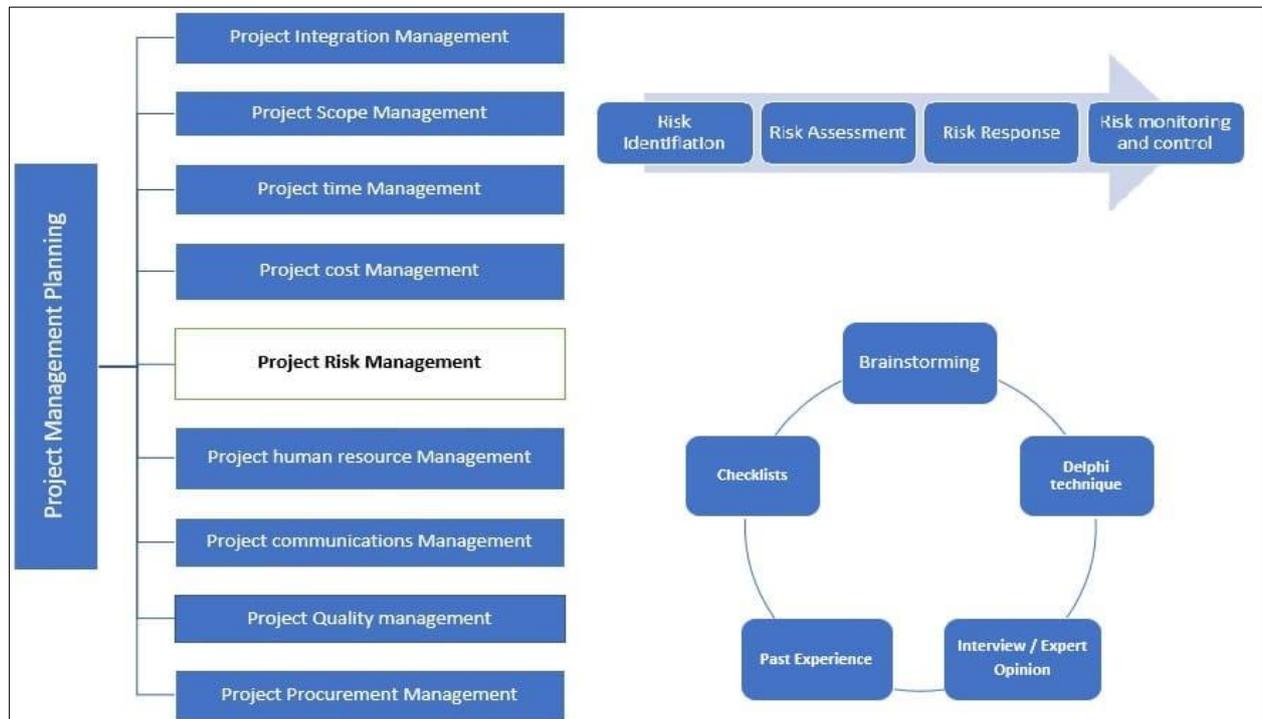


Figure 2 Risk Management in Construction Projects



Figure 3 Types of risks (financial, technical, legal, environmental, etc)

2.3. Cross-Disciplinary Collaboration in Civil Projects

While large infrastructure develops need multiple professionals including architects with engineers and contractors along with environmental scientists and public constituents to work together effectively the process remains difficult to manage. Various professions found at this intersection encounter challenges with their professional terminology because of their distinct values and because of conflicts that lead to communication breakdowns. Dewulf et al. (2007) demonstrates that productive collaborations need proactive administration of disciplinary disparities to block

operational flaws together with conflicts. The level of inter-participant integration determines success in transport infrastructure design projects because integrated relationships lead to project success or failure according to Löfgren (2020). Project managers of environmental initiatives tell Urton and Murray (2021) that developing improved team member relationships strengthens both stakeholder goal commitment and minimizes resistance to project modifications. The authors explain that communication problems maintain their position as a fundamental risk factor because inadequate collaborative process design leads to these communication issues.

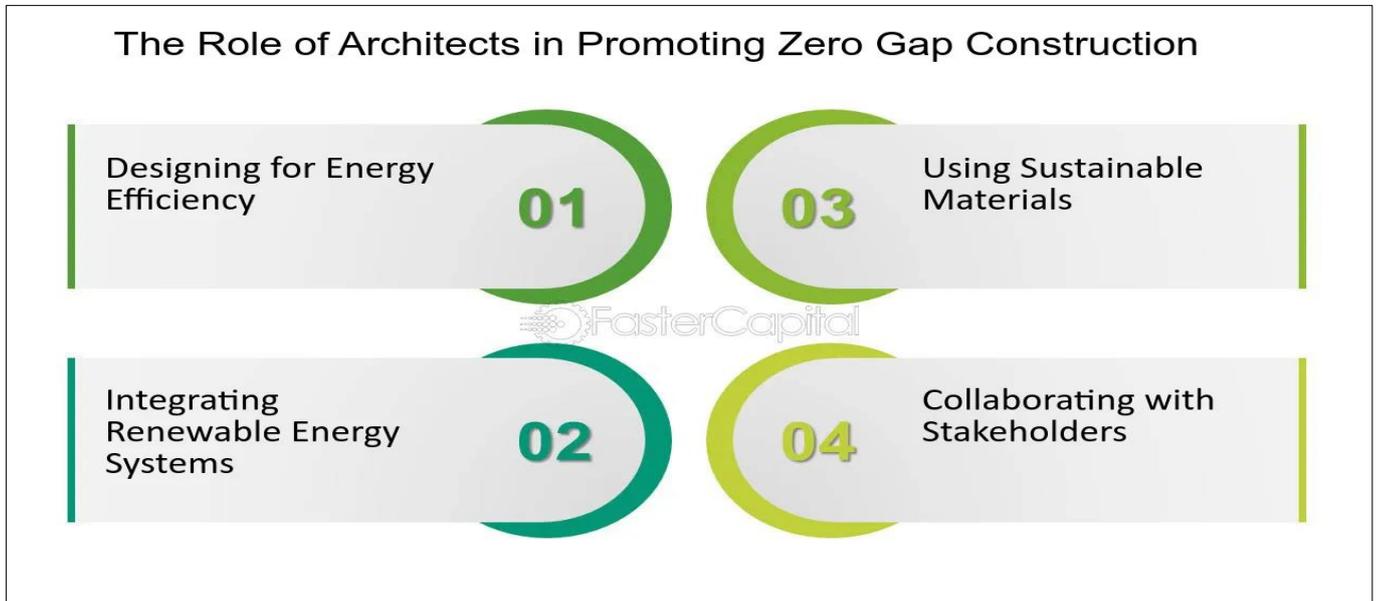


Figure 4 The Role of Architect and Engineers in Project Success

2.4. Existing Risk Assessment Models

Different types of risk assessment models exist in construction which includes both simple qualitative matrices and more complex quantitative simulations. Risk evaluation models with qualitative approaches depend on both expert analysis and historical records to establish risk divisions according to severity and probability levels and quantitative methods execute outcome predictions through probability analysis. The popularity of BIM-based risk analysis tools stems from their capacity to unite space-related and time-based project information. BIM operates as a tool according to Hasan et al. (2012) to assess crane stability under extreme wind scenarios thereby proving useful for dynamic risk analyses. A housing project received improved collaboration through integrated design and engineering which BIM facilitated according to Sebastian (2010). Zou et al. (2020) find fault with present model-based systems engineering workflows because they do not address vital socio-technical factors that matter in interdisciplinary collaborations. BIM-related research has increased significantly yet Jin et al. (2019) demonstrate that basic application of integrated risk frameworks faces obstacles in developing world regions.

2.5. Gaps in Literature

Current research about risk management and project delivery systems fails to provide sufficient solutions for complex interprofessional collaboration in Integrated Project Delivery (IPD) contexts. Current civil engineering projects need risk assessment models that support adaptive design structures but existing methods succeed best when working separately from each other. Risk assessment models operate within predefined boundaries to analyze preselected categories of risk issues but cannot process cumulative feedback from professionals who participate in a project throughout its process. The delay and fragmentation of risk response solutions occur because stakeholders fail to effectively use current project conditions and expertise for proper guidance.

Successful interdisciplinary cooperation requires stakeholders to develop mutual systems of language that allow them to exchange vital goals and concerns through shared understandable communication formats according to Dewulf et al. (2007). A lack of such frameworks makes it difficult for teams to combine their technical, managerial and contextual perspectives so they end up operating as independent units that prevent IPD's integrated strength. Project innovation serves as a "temporary trading zone" according to Lenfle and Söderlund (2019) because it needs teams with different

fields to cooperate by establishing shared conceptual tools for collaboration. Operation and cognitive integration play a vital role in determining the effectiveness of risk management based on the findings of research.

Adaptable models function as tracking systems for construction project developments regarding risk assessment. Sanni-Anibire et al. (2021) explain that machine learning technology integrated with intelligent systems helps develop instant risk identification methods for large project datasets. Predictive analytics focuses the team to redesign their strategies in advance instead of depending on fixed historical risk matrices. These adaptable tools supply instant responsive capabilities which lead to better accuracy and project-wide risk problem solutions.

Analysis tools in current use fail to indicate any method treating social or environmental elements in risk evaluation assessments. The framework development for complete evaluations requires combining stakeholder equity rating with measurements of community impact and environmental stewardship assessment as Valdes-Vasquez and Klotz (2013) argue. Risk assessments achieve success through the inclusion of research-backed factors that sustain projects and benefit the public. The current risk management practice should establish complete interdisciplinary systems to help social interests reach civil engineering success within Integrated Project Delivery.

3. Methodology

3.1. Research Design

The research combines qualitative and quantitative methods in a methodological mixing approach to evaluate cross-disciplinary risk assessment procedures on large-scale civil engineering projects using Integrated Project Delivery (IPD). Researchers combined two research approaches to identify both complex project dynamics and numerical risk analytics. The qualitative evaluation method brings together findings about engineering background and daily conduct from engineering professionals and personnel from architecture and project management fields. An extensive study provides researchers with vital information about how professionals approach collaborative risks in unclear project conditions.

By employing statistical models, the quantitative part of the study serves to evaluate risk-oriented data information. Research modeling enables scientists to develop fake scenarios of risk while identifying concealed data patterns that humans would otherwise miss when looking at data manually. Combined

qualitative and quantitative research produces outstanding power for analyzing complex civil infrastructure projects that span performance technology and human activities with institutional operations. Project delivery of socio-technical systems requires an integrated method that handles both objective data and subjective aspects based on Dewulf et al. (2007) and Löfgren (2020). This research design yields high validity with practical advantages when applied to civil engineering risk management activities in actual constructions.

3.2. Data Collection Methods

The quantitative methods used in this study include both practical field work and theoretical analysis to deliver extensive results regarding the identified problem. A comprehensive review of secondary data from literature forms the core of the main study which constructs an extensive empirical and conceptual foundation regarding Integrated Project Delivery (IPD) and its risk frameworks together with civil engineering inter-professional methods. The research uses the findings presented in Walker et al. (2022) together with Aktan et al. (2022) and Zou et al. (2020) about IPD strategies and stakeholder dynamics and risk modeling applied to complex infrastructure projects.

The researched data will assemble primary information from both semi-structured interview responses and structured questionnaires sent to specifically chosen field professionals. The research participants for this study include project managers together with civil engineers and architects who collaborate with Building Information Modeling (BIM) coordinators because they have direct experience with practical interdisciplinary risk management. Based on guidance from Urton and Murray (2021) the research subjects meet requirements because they participate in interdisciplinary project tasks. Gauging project dynamics demands surveys of people at the forefront of project experience to deliver credible information from their operational context.

In this third data collection technique, the case studies will be extensively analyzed in detail from the civil engineering projects that either recently completed or were in progress using the principles of IPD methodology. These case studies would be the empirical bases of this research as it demonstrates how cross-disciplinary collaboration and risk assessment practices take place in real time. Analysis of the documentation, team interaction, and risk outcomes for

these projects should allow the study to evaluate existing risk assessment models to identify weaknesses for improvement. Case-based evidence being included in the recommendations of Brncich et al. (2011) and Sebastian (2010) adds that theoretical research embedded in real projects would make theoretical research more applicable and relevant to industry practice.

3.3. Sampling Techniques

The purposive sampling method has been employed in this research as a pilot sampling strategy in selecting respondents for interviews and surveys. In nonrandom, criterion-based selection, usually useful for studies, are those whose intention is to learn from people with specialized knowledge and direct experience. The aim is to purposely include those professionals who are directly involved in IPD and multidisciplinary civil engineering projects, namely project managers, engineers, architects, and other stakeholders. Thus, the data collected stands a high probability of contextual relevance with real-life complexities.

It is another aim for purposive sampling so that the credibility and richness of research results could be increased. Rather than drawing inferences from a large, generalized population, the researchers felt it necessary to give voice to people who have been kept very close to the many collaborative struggles that sometimes-hard designs entail blocking. Their firsthand experiences differ with regards to cross-disciplinary coordination, risk identification, and coming with collaborative solution scenarios concerning risk management in such organizational settings.

This would be further endorsed by theorizing put forth by Lenfle and Söderlund (2019), advocating that large infrastructure projects must see as temporary trading zones. It is in this frame that myriad different disciplinary actors must construct a shared interlanguage so that communication can happen effectively with respect to project aims. The participant selection within these dynamic zones gives access to some tacit knowledge and adaptive strategies maneuvering across disciplinary borders, negotiating responsibilities, and attaining collaborative risk management. Thus, purposive sampling gives the study some extra methodological strength with results living in the experience of those most familiar with the realities of integrated project environments.

3.4. Data Analysis Techniques

Aside from just mixing quantitative and qualitative methods, the approach adopted for data analysis generally aims towards acquiring a fuller scenario of the subject of research considered for this study. As far as the qualitative aspect of data collection is concerned, thematic analysis will identify recurrent features, latent themes, and strong narratives revealing practitioners' perceptions and considerations of interdisciplinary risk factors and collaborative dynamics in IPD settings from interview data and open-ended responses from surveys. This will address both an exploration into some pretty deep local-context nuances and, beyond that, into wide-ranging shades of perspectives between stakeholders on what kinds of risks they face and how those risks are viewed or managed across disciplines for further consideration.

Meanwhile, the quantitative-oriented data obtained from questionnaires shall involve certain specific software tools for SPSS and MATLAB employed for such purposes for the analysis. The above output would enable some evaluation on the amplitude of frequency retardance of identified risks, perceived severities, and relationship between a few of these different kinds of risks and project outcomes. Hence, the actual study findings that are reached by way of applying statistical tests and modeling techniques will contribute to interpreting options from qualitative findings.

In summation, the dual approach applied here is inspired by Sanni-Anibire et al. (2021), which means that interpretive and computational strategies are put together while developing adaptive risk mitigation frameworks for construction projects. This dual perspective-a thematic analysis and data-oriented scheme-is envisaged to give the research insights into stakeholder experiences and measurable patterns affecting the risk through IPD settings. Such analytical frameworks will build strong interdisciplinary risk models on theoretical and practical grounds.

3.5. Model Development

This is the entry-government of an interdisciplinary approach to research IPD and learning in highly specialized areas. Between them are conduits for system-mindsets and machine learning by these very deep, not very mainstream considerations that might attract motivation for these non-mainstream systems-dynamics and machine-learning-motivated modeling-theories-risk behaviors: for none other than these MBT methods are dealing with hyper nonlinear interdependence, with ridiculous matrixes of interventions from a range of disciplines-such as project programming, for example, architect-engineering, and construction management scheduling-bursting through activities inside massively complex projects-those very interdependencies that are almost shading them. Some kinds of system-dynamic

modeling, at least, manage the long feedback loops, time delays, and causal structures that mainly try simulating and attending during their formative phase the complexity projected to envelope the whole project ecosystem. Perhaps

whatever affects a project system finds an intersection or another to anchor on; otherwise, disruptions likely accumulate momentum to be thrust into considerations of other project systems as they gain traction.

Machine learning may just give another sustaining reason that, of course, will be being viewed under input-output-real time data with respect to any trends that might or could have happened for a specific prediction model. Conversely, only enough engagement with this machine-learning model will warn the user of precursor-to-risk knowledge and suggest appropriate mitigations via further data feeding into that knowledge set. In 2020, Zou et al. portrayed quite well how socio-technical considerations ran; however, considering the complexities of interdependence within interdisciplinary systems, this has undercut their very argument of linear modeling. It indicates the need for the dynamic framework to elicit relevance within a context where quick-changing project parameters are creating significant junk.

Here is yet another avenue opened for responsible machine learning to prove application in adaptive, data-centric models to study and explicate phenomena of construction delay (Sanni-Anibire et al.). Of course, algorithmic tools would be expected to predict disruption and avert it. This model thus continues operating on a dynamic basis as it learns from progressive real-time input on outputs from multiple disciplines. This should, henceforth, bring out a solution for risk assessment at commercial and scalable level for environmental integration on project delivery, hence bridging the gap of theoretical models to contemporary practice in civil engineering.

4. Results and Discussion

4.1. Identified Cross-Disciplinary Risks

Various risks at the intersection of several different fields were found affecting an Integrated Project Delivery (IPD) based on research study findings. All these aforementioned risks were collected and categorized according to interviews, questionnaires, and case study evaluations. They are more likely sources of breakdown in communications, conflicting professional priorities, and misaligned technical terminologies according to DeWolff et al. (2007) and Ienflé and Sörerland (2019). For instance, structures as per most engineers do consist chiefly stability, durability, and structural cost efficiency towards having them rated lower on aesthetics and spatial quality as would also be under costs with inability to work such differences at the beginning in a project lifecycle causing an increase in scope, schedule, and safety concerns. Then, tools that would speak about such digital tools being fragmented across disciplines such as inconsistent Building Information Modeling (BIM) adoption only increased complexity as discussed by Li et al. (2019) and Jin et al. (2019). In this regard, these risks further demonstrate the importance of establishing mechanisms that could not only integrate the workflow but also ensure continuous bi-directional flow of knowledge.

4.2. Evaluation of Existing Risk Models

In plain words, most of the existing frameworks referred to as risk evaluation do not account for interdisciplinary collaboration differences. Traditional modes of risk management are likely to deal with the identification and evolution technically of risk within projects, but how ever one might say with some readying of comfort that it does not concern itself with cultural, relational, and communicative problems arising in such cross-disciplinary endeavors. After assessing the documents and stakeholder points of view, it might be easily thought that most of such models concerning random arguments are linear and reactive rather than system based and adaptive. Walker et al. (2022) have similarly said that such an old touch can hardly suit the conditions like IPD where rapid feedback and shared control are essential. These existing tools, to another aspect, cannot even integrate real-time project information from domain stakeholders therefore discrediting justified decision-making. The risk management systems that are being framed now as new designs by Zou et al. (2020) and Sanni-Anibire et al. (2021) have been more promising in concentrating upon emergent risks and forecasting interdependencies involved by data-driven and socio-technical principles. As a result, this denies performance directly and supports the conclusion that risk models need to be developed not only with regard to estimating known hazards but also evaluating risk dynamically via real-time hazard assessments modified by changing contingent events and capabilities of the project.

4.3. Proposed Cross-Disciplinary Risk Assessment Framework

The knowledge base thus makes the inclusion of risk impacts through the confines characterizing each of the risk management models with several qualitative and quantitative boundaries. Further inter-institutional integration describes how a project risk will be modeled through system dynamics and machine learning to gather inputs from many stakeholders simultaneously, along with real-time data feeds into socio-technical mapping of project risk

feedback loop modeling. All will serve as an initial setting that again and again will feed new data into supervised learning algorithms to impact significance of risks as initiated by Sanni-Anibire et al. (2021)-here the implication of integrated socio-technical variables will affect behavioral characteristics of project risk at the organization level as defined by Zou et al. (2020) especially with reference to frequency of communication and independence in decision making-.By this flowcharting and interactive dashboards will visualize the whole workflow of the project manager and the team lead, with real-time updates about identified risks, causes, and what may be done by way of mitigation. Risk matrices actually define threats in terms of severity and likelihood; these multilayered analyses run in the thousands "risk impacts across the limits of every risk management model, coupled with various qualitative and quantitative borders." "Further inter-institutional integration defines" "flowcharting" and "risk matrices" will define threats in terms of severity and likelihood; thus, risk parameters range into thousands".

The prototyping assumes system modeling for already existing ones on the predictive quality and quantitative empirical indicators of a notorious interdisciplinary project. Cosmologically, the developing prototype system dynamics modeling and applications of machine learning, primarily with heaven interpretation, avows differentiation across disciplines in predicting escalating risk events during the entire project life cycle. Such dynamic qualities attributed to the model itself would bring together interfaces for stakeholder input; real-time integrated data from project management tools; socio-technical mapping functionality; and adaptive feedback loop machine. This according to the ground setting with which the framework is built under supervised learning algorithms as thus enunciated by Sanni-Anibire et al. (2021), whereby again, new data determine the value of importance in risk. There were also certain socio-technical variables that required integration, such as the endogenously defined communication frequency and independence in decision-making, as Zou et al. (2020) convincingly argued that the technological set-up affects project risk levels. Flowcharting and interactive dashboards would represent the entire workflow such that the latest status report on identified risks, root causes, and possible mitigating measures reach any manager or team leader. There is also incorporated a tool to compute the risk matrix, assessing threats by effectiveness evaluated in hours multiplied against likelihood on cross-disciplinary domains.

4.4. Validation of the Proposed Model

Establish validation using comparison with conventional risk assessment frameworks that score on the criteria of relevance to IPD projects. The outcomes from retrospective case studies and practices showed that the model just described will enable the early identification of risks and agreement among the entire project party on risk mitigation strategies at optimal time flexibility. Further evidence was gathered from feedback of an active panel composed by managers, civil engineers, and design consultants in the industry. They all agreed to it helping to close the communicative and functional gaps, and thus laying the foundations for developing a common language and risk perception framework as expressed in Dewulf et al. (2007) and Löfgren (2020). The experts fervently advocated for the interactive interface for the model complemented by options for scenario simulation for informed joint decision-making and planning. The model's significant adaptability was considered particularly timely-with regard to time, sustainability, and resilience raised by Aktan et al. (2022). Certainly, the validation is clearer toward improved pathways of interdisciplinary risk governance for big civil infrastructure projects in practice.

5. Conclusion

Summary of Findings

The risks involved with Integrated Project Delivery (IPD) forms, generally and interactively, have been studied between disciplines in the mega-project context in civil engineering. Now, most of the risks emerging are found to come from the particular disciplinary contexts in which these specific professions have their own conceptual, procedural, and communicative boundaries after analyzing the entire findings. Thus, conflicts in value systems and nomenclatures, and also priorities, within the aforementioned boundaries become sources for inefficiencies and misconstructions of all forms over the entire life cycle of the project. They are hence the agents for many conflicts. The vulnerable areas around those interfaces are what is caused by similarities in pattern caused by these misaligned workflows and inconsistent variables of collaboration.

It seems to run, however, with the argument made by Dewulf et al. (2007), who seem to agree on the initiation of efforts for a joint understanding and framing in cross-disciplinary cooperation. Exchange zones for the temporary sharing of ideas could very well be the one other way forward that the diverse specialists will have to find themselves in a concentrated effort with one another using an ever-broadening interlanguage that would then support their collective action at the site (Lenfle & Söderlund, 2019). With there not being such a framework for interaction in infrastructure

projects, the produce is virtually a minefield of dangers and holdups for construction and operations processes due to fragmentation of the critical disciplines in engineering, architecture, environmental sciences, and digital technologies.

This delves deeper into asserting that any traditional risk management model, by very nature of its basic structure, would not succeed in making attempts to capture the dynamism and ever-fluid cross-disciplinary context. Even an appraisal of its very basic assumptions will be old: assumptions are static in nature, they establish linearity of processes, and classifications are rigid. That's true scary as applied to those projects which have basically been called by names signifying ever-continuous changes, very high uncertainties, and extreme collaborative complexities in their application. In the contrary, the model for cross-disciplinary risk assessment put forth by this research is a model whereby system dynamics modeling and machine learning are evermore wed for enhancing the responsiveness and adaptability of risk analysis. And that relates to the ability to simulate feedback mechanisms initiating changes to historical and real-time datasets; thus, allowing stakeholders to proactively identify emerging risks and adjust their mitigation action plans accordingly.

Contributions to Knowledge

Particularly important has been this research's emerging contribution to addressing risk assessment for the increasingly extensive and joint-sponsored civil-engineering projects within the scope of Integrated Project Delivery (IPD). In this developed, emerging new paradigm for contemporary risk management, it actually introduces what is termed as adaptive risk assessment model with complete synthesis of socio-technical dimensions. Note that the real strength of the model lies in its ability to adapt to various ongoing modifications in the current projects in terms of parameters and assumptions, including schedules, budgets, resources, and concerned people.

This flexibility embodies definitions of modern construction projects, which are mostly evolving without prior notice or radically changing project conditions that can affect their completion. Instead, is a more complicated, agile paradigm that replaces a classical linear and all-in-one approach for risk management. Any risk assessment would realistically be applicable and pertinent throughout the entire lifecycle of the project, as achieved through continuous feedback and collective real-time integration of project data. This way of real-time monitoring and adaptivity is completely consistent with what has called for interdisciplinary risk management strategies, which are basic to resilience and sustainability in planned infrastructure, according to Aktan et al. (2022).

This enables real-time monitoring and adaptation to dynamic changes in the project; all the useful inputs go directly to the stakeholders for informing their decision-making processes, thus increasing the chances for satisfactory project outcomes. There is synergy created between stakeholder input systems and AI-assisted tools to purport major advancements in assessing and mitigating risks in construction projects. This framework employs artificial intelligence and machine learning algorithms in making the anticipation data based on its probable risks and adaptive tactics to those risks. With this, the assumptions would develop to allow much more precise risk analysis, as all of this is a completely pro-active-predictive tool since it claims to go beyond what's emerging in today's thinking of Construction 4.0 as saw by Koc et al. (2020). That's a completely novel sort of dimension which is going to deal with construction risk with far better accuracy, scalability, and efficiency in a forthcoming paradigm shift where AI technologies will vault themselves into traditional project management.

Recommendations

The report provides many options for researching the various problems associated with big infrastructure projects. For example, it has cited an appreciable number of concrete recommendations to transform and update the boundary conditions under the governance framework to the end of transdisciplinary collaborations with policy-makers and regulators. Such collaboration will face the challenge of engaging training sessions for mutual upskilling in interlanguage communicability, wherein civil engineers, architects, and project managers will together become more efficient with regards and with an ever-lessening number of cases of misunderstandings and fatalities arising from the silos of the disciplines, as asserted by Lenfle and Söderlund (2019). Meanwhile, format should be supportive of pre-research integration across an array of disciplines to provide timely input on behalf of real stakeholders. This calls for participation by actual stakeholders from the onset, usually to provide guidance to decision-making under a more integrated project management environment.

There ought certainly to be one understanding of risk and risk management among engineers, project directors, and consultants. For a number of years, they considered risk only within the compartment of technical hazards. The actual paradigm to be applied in any perceived threats to present large-scale infrastructure projects would be integrated risk management in the broadest possible sense. This should incorporate organizational behavior, team dynamics, and even digital interoperability-with a case to be argued for active leadership in fostering culture of inter-project cooperation

as strongly advocated by Urton and Murray (2021). Then to provide the key to the doors for cross-disciplinary collaboration, leaders connect different bodies of knowledge while permitting diverse perspectives to robustly interact and enrich perspectives within project teams to see and deal with the universe of challenges that can thwart the successful realization of the objectives.

Only the very powerful implementations such as the digital agency's cosmologies actually may encompass risk management. This would mean that it would finally feed on BIM, AI, and real-time analytics. Methodologies are complex enough to require fair numbers of stakeholders, but on the other hand, applying those to the risk management methodologies proposed by Sebastian (2010) and Jin et al. (2019) would certainly clarify most of the uncertainties. These integrations will indeed take shape and help in coordination and communication to eventually improve the accuracy of risk assessment and, ultimately, the performance of projects in the longer term. The output of this virtual presentational software is the real-time simulation of the construction process along with predictions on adverse risks that could occur by AI based either on the latest or historical data. All these technologies and their applications would thus get crossed, proving beneficial in risk treatment and complexity management of the project.

This would mean doing so in risk management, such that projects would be constrained by climatic conditions or environmental impacts, thus interfacing such projects with ideas of environmental sustainability as well. This emerging trend will further fortify to such an extent that risk management practice will certainly address long-term environmental and climate perspectives. The frameworks developed by Lisø (2006) and Wei et al. (2020) would constitute a very good basis for such regulation. These facilitate the enhancement of adaptive resilience in infrastructure development; planning for change impacts on infrastructure development; embedding environmental sustainability in risk assessment processes; and ultimately sustaining overall project resilience much of these under altered environmental conditions. This will therefore in brief give an agent that eventually generates these differences in future endures a tool of adaptation for the future in response to changes of the environment by climate change.

Table 1 Showing the Actionable Recommendations for Enhancing Cross-Disciplinary Risk Assessment in Large-Scale Infrastructure Projects

Stakeholder Group	Recommendation Area	Specific Actions
Policymakers & Regulators	Governance Reform	Revise project governance frameworks to support cross-disciplinary collaboration. Introduce training programs for interlanguage communication.
	Early Integration	Promote interdisciplinary collaboration from project planning stages.
Engineers, Project Managers & Consultants	Holistic Risk Identification	Broaden scope of risk management to include team dynamics, organizational behavior, and digital interoperability. Encourage leadership that nurtures collaborative culture.
	Leadership Role	Foster leadership that supports and sustains cross-disciplinary teamwork.
	Digital Tool Adoption	Utilize BIM, AI, and real-time analytics for improved coordination and communication. Use digital simulations for proactive risk identification.
Project Stakeholders Facing Environmental Risks	Climate-Sensitive Risk Management	Align risk strategies with sustainable and adaptive environmental frameworks. Integrate climate impact planning into risk assessments.

Suggestions for Further Research

These further research initiatives should enrich the existing model with some capabilities for real-time acquisition and analysis of the data and hence enable it to learn and update risk scenarios continuously from live project performance indicators. Such a redesign would require incorporation with IoT devices, digital twins, and cloud BIM applications, thereby making the model additionally responsive and predictive, as pointed out by Hasan et al. (2012); therefore, other

empirical studies will be needed to validate the usability of the model for different kinds of infrastructures- highways, bridges, dam construction, etc.- that exemplify highly interdependent disciplines and thus provide very good ground to test the proposed scalability and adaptability of the framework. However, this testing will be further strengthened with reference to Valdes-Vasquez and Klotz (2013), who reiterated social and technical aspects in determining sustainable design outcomes. Therefore, in view of the ongoing digitization and integrated project delivery in the industry, there is a pressing need for innovative and dynamic or cross-disciplinary developments in risk management strategies.

Compliance with ethical standards

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

- [1] Dewulf, A., François, G., Pahl-Wostl, C., & Taillieu, T. (2007). A framing approach to cross-disciplinary research collaboration: experiences from a large-scale research project on adaptive water management. *Ecology and Society*, 12(2).
- [2] Aktan, A. E., Brownjohn, J. M. W., Moon, F. L., Sjoblom, K. J., Bartoli, I., & Karaman, S. G. (2022). Civil engineer for urban livability, sustainability and resilience. *Sustainable and resilient infrastructure*, 7(5), 480-491.
- [3] Walker, D. H., Vaz Serra, P., & Love, P. E. (2022). Improved reliability in planning large-scale infrastructure project delivery through Alliancing. *International journal of managing projects in business*, 15(5), 721-741.
- [4] Cherukuri, B. R. (2020). Microservices and containerization: Accelerating web development cycles.
- [5] Löfgren, S. (2020). Designing with differences, cross-disciplinary collaboration in transport infrastructure planning and design. *Transportation research interdisciplinary perspectives*, 4, 100106.
- [6] Masurkar, P. P., Chatterjee, S., Sherer, J. T., Chen, H., Johnson, M.L., & Aparasu, R. R. (2022). Risk of serious adverse events associated with individual cholinesterase inhibitors use in older adults with dementia: A population-based cohort study. *Drugs & Aging*, 39(6), 453-465.
- [7] Li, P., Zheng, S., Si, H., & Xu, K. (2019). Critical Challenges for BIM Adoption in Small and Medium-Sized Enterprises: Evidence from China. *Advances in Civil Engineering*, 2019(1), 9482350.
- [8] Lisø, K. R. (2006). Integrated approach to risk management of future climate change impacts. *Building Research & Information*, 34(1), 1-10.
- [9] Van Rooij, S. W. (2010). Project management in instructional design: ADDIE is not enough. *British Journal of Educational Technology*, 41(5), 852-864.
- [10] Zou, M., Vogel-Heuser, B., Sollfrank, M., & Fischer, J. (2020, December). A cross-disciplinary model-based systems engineering workflow of automated production systems leveraging socio-technical aspects. In *2020 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 133-140). IEEE.
- [11] Kilari, P. W., & Dhires, S. (2022). Deep residual learning for image recognition. *IRE Journals*, 6(1), 780-783. *Iconic Research and Engineering Journals*.
- [12] Sanni-Anibire, M. O., Zin, R. M., & Olatunji, S. O. (2021). Machine learning-Based framework for construction delay mitigation. *Journal of Information Technology in Construction*, 26.
- [13] Brncich, A., Shane, J. S., Strong, K. C., & Passe, U. (2011). Using integrated student teams to advance education in sustainable design and construction. *International Journal of Construction Education and Research*, 7(1), 22-40.