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Article

Based on BIM intelligent technology and IPD collaborative management model applied to characteristic towns with PPP mode

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Abstract: The recent development of characteristic towns has encountered a multitude of challenges and chaos. Nevertheless, there have been many instances of information asymmetry due to the absence of an effective management model and an intuitive digital management system. Consequently, this has caused the erosion of public interests and inadequate supervision by public agencies. As society is progressing at a rapid pace, there is a growing apprehension regarding poor management synergy, outdated management practices, and limited use of technology in traditional construction projects. In today's technologically sophisticated society characterized by the "Internet+" and intelligent management, there is an urgent requirement to identify a more efficient collaborative management model, thereby reducing errors caused by information asymmetry. This paper focuses on the integration of building information modeling (BIM) and integrated project delivery (IPD) for collaborative management within characteristic towns in the PPP mode. By analyzing the available literature on the application status, this study investigates the implementation methods and framework construction of collaborative management while exploring the advantages and disadvantages. On this basis, this study highlights the problems that arise and provides recommendations for improvement. Considering this, the application of the BIM-based IPD model to characteristic towns in PPP mode will enhance the effectiveness of collaborative management among all parties involved, thereby fostering an environment that facilitates decision-making and operational management in the promotion of characteristic industries.

Keywords: characteristic town; public-private partnership (PPP); building information modeling (BIM); integrated project delivery (IPD); collaborative management

1. Introduction

A characteristic town, otherwise referred to as a novel form of settlement, combines various elements such as industry, community, tourism, and culture. This area is characterized by the convergence of characteristic industrial projects, with industry serving as the central focus and the integration of various aspects of life, production, and the ecological environment. To achieve robust development, it is crucial to establish a secure and sustainable source of funding as well as an efficient collaborative management mechanism involving multiple parties (Collaborative Management, 2023). This indicates that collaborative management that hinges on local conditions is of primordial importance for a characteristic town (Zhou, 2020).

An overwhelming majority of regions across China have applied the public-private partnership (PPP) mode to facilitate the development of characteristic towns. This approach primarily emphasizes collaboration between the government and private investors in public services and infrastructure construction (Collaborative Management, 2023; Zhao, 2021). The efficient implementation of digital management throughout the construction of a characteristic town in PPP mode greatly enhances

control over the construction process. This can be achieved by establishing an effective information exchange platform, which enables real-time supervision and management of the project.

This study focuses on the integration of building information modeling (BIM) and integrated project delivery (IPD) to explore a novel approach for investment management of characteristic towns in the PPP mode. The objective of this study is to address decision-making errors and inadequate supervision due to information asymmetry. The IPD model demonstrates its effectiveness in seamlessly integrating the different phases of project implementation and all parties involved, thereby satisfying the requirement of collaborative management in construction projects. BIM, on the other hand, is a modern 3D building information technology platform that enables the use of parametric models. The introduction of the IPD collaborative management model supported by BIM technology allows all parties involved in characteristic town construction to share information and make informed decisions on the platform based on their specific requirements. This has the potential to bring significant advancements in project management for characteristic industries, address the limitations of traditional management models, and effectively improve administrative efficiency and management performance (Guo, 2019).

2. Review of literature

Using BIM information technology and the Internet to build a financial information investment management and control platform integrated with BIM project management platform can help innovate investment projects and achieve rapid economic development. In the past, due to information asymmetry, there were many phenomena caused by difficulties in promotion:

(1) The traditional investment management and control model had high decision-making risk and low decision-making speed.
(2) For traditional investment control, it only focused on passive audit after the fact, and could not complete the whole process of active audit.
(3) By publishing financial information on the BIM project management platform, power can be carried out under the sun, giving full play to the immune function of national law and protecting the safety of leading cadres and national financial funds.
(4) Using data accumulation and establishing a Big Data can improve future decision-making and scientific continuous improvement.

2.1. BIM technology

BIM is a digital framework that encompasses both functional and physical characteristics, serving as a collaborative platform for sharing resources and project data. BIM technology demonstrates its capability to create dynamic building models that are rich in visual information. This enables all parties involved to contribute the required information at various phases of the project, facilitating integrated management of engineering safety, quality, progress, and cost (Hou, 2021). The provision of a reliable basis throughout the project is of utmost importance for decision-making. All parties involved can promptly update and modify information

within the BIM system, thereby accommodating their collaborative operational needs (Guo, 2019; Huang and Yao, 2017).

2.2. IPD model

In response to the professionalization and integration of construction projects, the IPD model has emerged as a comprehensive framework for project performance management. This model integrates all parties and resources involved in each phase of project performance management, where performance information can be effectively exchanged and shared among all parties involved. The achievement of integrated management and the agreed delivery of project performance are considered the shared goals of all parties involved in the project (Guo, 2019).

The IPD model has resulted in substantial improvements in the traditional delivery methods, as shown in **Figures 1** and **2**, thereby significantly enhancing collaboration, and facilitating information sharing among all parties involved while minimizing resource waste (Yang, 2017; Yang, 2015).

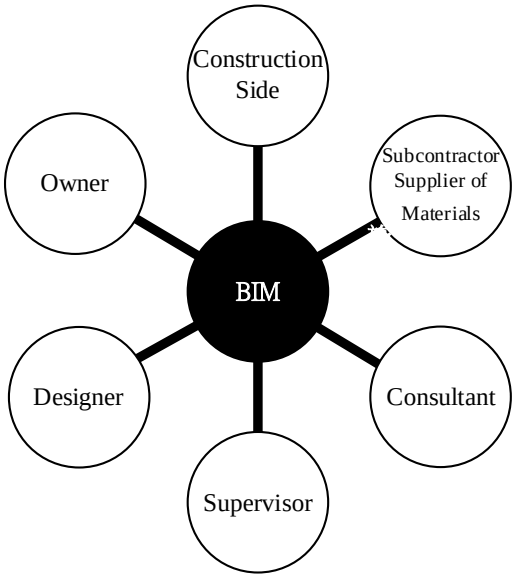

Figure 1. Inter-organizational communication within the BIM model (Yang, 2017).

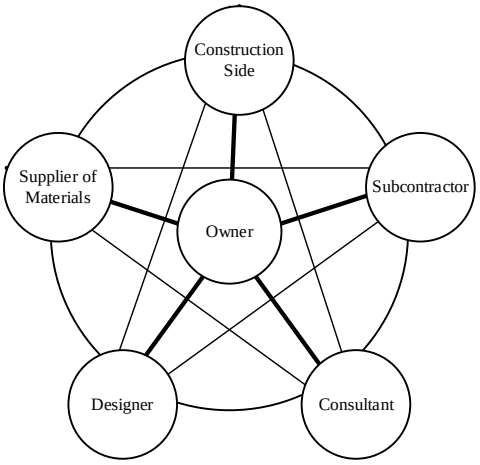

Figure 2. Inter-organizational communication within traditional management models (Yang, 2017).

2.3. The interplay of BIM and IPD

BIM exploits its technical advantages to the fullest in supporting the IPD model, which, in turn, provides a broader framework for the development of BIM. The integration of the two provides the most comprehensive perspective and enables a forward-looking focus (Guo, 2019). The four reasons underlying this are as follows:

(1) BIM technology provides robust technical support for the IPD model, serving as its technical foundation. The BIM technology, coupled with the IPD model, assures project teams of efficient intelligent management and information sharing, offering promising assurance for engineering quality and efficiency.

(2) The IPD model incorporates various project resources, with BIM serving as the core technology. This greatly enhances collaboration among all parties involved, leveraging their respective potentials to achieve optimal performance and cost control.

(3) Within the IPD model, all parties involved share the same goals. Through the utilization of BIM technology, an information-sharing platform is established to disrupt the traditional management models characterized by structural dispersion and information asymmetry.

(4) The inherent attributes of BIM technology, such as information integrity, information relativity, and the capacity to replicate graphic information, allow all parties involved, including owners, designers, and others, to efficiently establish a digital design model through annotated information. This facilitates the visualization and simulation of architectural structures, allowing for a thorough analysis and evaluation of their structural performance. Additionally, it enables the incorporation of green and energy-saving features. All of these contribute to the improvement in the lifecycle design and the reduction in the project cost.

2.4. BIM and intelligent technology interaction trend

Building information modeling (BIM) and the Internet of things (IoT) in intelligent buildings. By leveraging these technologies, we can better manage building performance, improve efficiency, and promote sustainability, providing strong support for future developments in smart building design and management. Recent studies are as follows:

(1) Colace et al. (2023) introduces BIM-based decision support system to assist decision makers in making informed decisions about the management and development of intelligent buildings. This approach can enhance decision-making effectiveness and reduce the risks associated with building projects (Colace et al., 2023).

(2) Chen et al. (2023) introduces BIM and IoT to achieve sustainable buildings. By integrating these two technologies, buildings can be monitored in real-time to optimize energy usage, reduce waste, and improve overall sustainability. This approach can help reduce environmental impact and promote sustainable urban development (Chen et al., 2023).

(3) Congiu et al. (2023) introduces a web-based management approach for public buildings that integrates BIM, IoT sensors, and a Web-GIS portal. This approach can improve building efficiency, reduce maintenance costs, and enhance public safety by enabling real-time monitoring of building status and performance. This can lead to

better management and operation of public buildings, benefiting the community (Congiu et al., 2023).

In summary, these three articles provide important contributions to the field of intelligent building design and management by exploring the potential of BIM and IoT technologies. The insights and methods presented in these articles can serve as a foundation for future research and development in this area, leading to more intelligent, efficient, and sustainable buildings.

2.5. BIM-assisted AEC project solutions

In the AEC industry, BIM (Building Information Modeling)-based solutions can help achieve more efficient, precise and reliable project management and construction. Here are some BIM-based solutions:

(1) BIM collaborative design: By using BIM software, design teams can collaborate on a platform to achieve more efficient design and coordination, which can reduce errors, improve design quality, and speed up the design process.
(2) Conflict detection and coordination: Utilizing the visual nature of BIM technology, conflict detection and coordination can be performed during the design and construction stages to ensure collaborative work between different professionals and teams.
(3) Parametric design: By using parametric design tools, designers can quickly adjust designs based on project requirements and parameters to improve design flexibility and efficiency.
(4) Prefabricated component design: Utilizing BIM technology, prefabricated components can be designed and produced to improve construction speed and efficiency.
(5) Construction simulation: By using BIM software for construction simulation, the construction process can be predicted and optimized to reduce errors, improve efficiency, and reduce costs.
(6) Cost estimation and budgeting: By utilizing a BIM model, more accurate cost estimation and budget preparation can be performed to help project managers better control project costs.
(7) Visualization, making the presentation of design proposals more accurate and vivid.
(8) Sustainability assessment, measuring the environmental impact of design proposals.
(9) Historic building preservation, capturing detailed information of historic buildings for their protection and record-keeping. These solutions can help improve efficiency, accuracy, and reliability in the AEC industry.

Overall, BIM is driving innovation and improving decision-making, efficiency, and quality in the AEC industry, as shown by its applications in visualization, sustainability assessment, and historic building preservation.

3. Methodology

3.1. Status of the BIM-based IPD collaborative management model

In China, there are still challenges with the integrated delivery of BIM-based collaborative management in PPP projects. These challenges include (Xiao and Cao, 2021):

(1) Design-bid-build (DBB), the traditional method of project delivery, is still widely used in China, with a common problem of ineffective information communication.

(2) The application of BIM technology in China's construction industry has room for improvement. The utilization of this technology depends primarily on prominent design enterprises and iconic buildings. However, there is a promising development prospect with the increasing number of successful applications in recent years (Hou, 2021).

(3) Although the government is continuously promoting the development of BIM technology through policies, its relatively short time since being introduced into China has caused a growing number of problems to be solved in its application in the construction industry.

(4) The absence of a comprehensive standard protocol for industry data in China hinders the attainment of resource and information sharing.

3.2. Problems addressed by the BIM-based IPD model.

The BIM-based IPD model effectively addresses the difficulties mentioned thereon. The IPD model exploits its superiority to the fullest in terms of cost control, schedule assurance, and collaborative management, enabling all parties involved to share resources and information within the BIM system and promoting a clear definition of rights and liabilities for information exchange (Xiao and Cao, 2021). Comparison of the advantages and disadvantages of the BIM-based IPD collaborative management mode. It is found that the BIM-based IPD model can cause both Party A and Party B to have many advantages and reduce the disadvantages, improve the efficiency of the overall project operation mode, and benefit the whole life cycle of the project (**Table 1**).

Table 1. Comparison of the advantages and disadvantages of the BIM-based IPD collaborative management model.

	Party	**Descriptions**
Advantages	Party A	Make informed decisions, achieve business goals, and ensure the smooth implementation of projects. Ensure information transparency throughout the project lifecycle by promoting collaboration, information sharing, and mutual trust among all parties involved, and minimize design changes during implementation. Regular communication in the IPD model among all parties involved can ensure the effectiveness and interoperability of information (Xiao and Cao, 2021). Facilitate data integration and information exchange among all parties involved, thus improving the efficiency of project development. Identify risk points and develop response measures in the initial phase of the project.

Table 1. (*Continued*).

	Party	Descriptions
	Party B	Carry out initial modeling and collision detection, reducing the time for document transfer among parties. Lead to cost reduction, a shorter construction period, fewer revisions, and guaranteed progress (Xiao and Cao, 2021).
	Both parties	Each party is strongly encouraged to effectively leverage their expertise and experience for collaborative management. This model can be extensively utilized in various phases, such as engineering decision-making, design, implementation, and acceptance, to exploit its advantages of collaborative management to the fullest. Ensure that risk management aligns with the common interests of all parties involved, fostering a community of shared interests (Xiao and Cao, 2021).
Disadvantages	Party A	The competition between Party A and Party B hinders the cultivation of trust.
	Party B	Unclear definitions of rights and responsibilities may result in responsibility avoidance.
	Both parties	Barriers arise in risk sharing and profit distribution, such as disagreements over allocating intangible assets or unexpected income generated during project management.

Source: Cao, 2012; Xiao and Cao, 2021; Zhang et al., 2022; Rao and Wang, 2021; Kou, 2020.

The BIM workflow encompasses various phases of construction projects, including planning, design, construction, and operation management, catering to the needs of owners, designers, units in charge of construction, consultants, and supervisors. The BIM-based IPD model is an integrated process developed based on consultation, design, construction, operation, and project information, as shown in **Figure 3**.

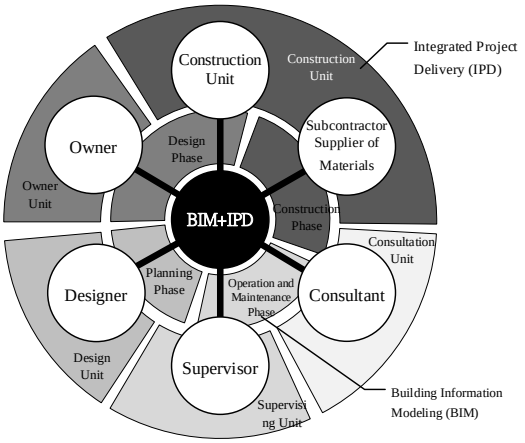

Figure 3. Conceptual construction of the BIM-based IPD collaborative management model.

The application of the BIM-based IPD model to PPP projects has the following advantages (Xu et al., 2011; Zhang and Zhao, 2011; Jasper et al., 2020):

(1) The IPD model, akin to BIM technology, is an integrated method.

(2) The IPD mode can unleash the full potential of BIM technology.

(3) BIM technology provides technical support for the IPD model, facilitating value realization.

(4) The IPD model expands the application of BIM technology beyond parts of engineering construction, promoting diverse applications of BIM technology (Wang and Hou, 2015; Du, 2015; Cao, 2012).

3.3. BIM intelligent technology and IPD integrated and applied technology detail

In a project management framework, BIM intelligent technology and IPD Collaborative Management Model can be integrated and applied at different stages and components (**Table 2**).

Essentially, BIM Intelligent Technology and IPD Collaborative Management Model can be deemed as tools in project management that can be employed at different stages of a project as needed. This integrated approach enhances project efficiency, quality, while reducing risks and costs.

Table 2. BIM intelligent technology and IPD integrated and applied technology detail.

	Early stages	**Design phase**	**Construction phase**	**Operation and maintenance phase**
BIM intelligent technology	It can be utilized for needs analysis and design. For example, AI can be used to conduct deep learning and analysis of project needs, generating initial design options.	It can further contribute with tools such as big data analysis, cloud computing for design optimization and analysis.	It provides intelligent support for construction process simulation, construction progress monitoring, etc.	It can be utilized for facility management and maintenance, such as intelligent energy management and equipment maintenance.
IPD collaborative management model	It can be employed to bring together stakeholders such as owners, designers, and contractors for aligning project goals and expectations.	It ensures that the needs and feedback from all parties are adequately considered and addressed.	It enhances communication and collaboration among all parties to ensure smooth construction progress.	It aids in maintaining coordination and relationships among all parties to ensure long-term project sustainability.

4. Results

There are distinctions between IPD and traditional delivery models. Traditional delivery models suffer from information silos, which can be prevented by applying the IPD model to collaborative work. This model enables all parties involved to develop a close relationship, thereby achieving mutual restraint and risk reduction (Wu, 2013).

Furthermore, this model facilitates all parties involved to establish close cooperation in every phase of the construction project, efficiently increasing the project's profit and maximizing its benefits.

The IPD model solves this problem effectively. The BIM-based IPD model promotes risk sharing and strengthens collaboration among all parties involved, thereby reducing the probability of problems arising during the later phases of construction. Hence, it is evident that BIM serves as a crucial foundation for the IPD collaborative management model, and both are indispensable.

4.1. BIM-based IPD collaborative management model

The IPD model for collaborative work is based on the establishment of team-based organizations, the definition of roles, responsibilities, and scopes of services for participants, as well as the determination of project outputs and evaluation criteria. A construction project in the IPD model is divided into nine distinct phases that encompass the entirety of the project management lifecycle. These phases include the project concept, surveying and mapping, project design, tendering and bidding, project construction, project operation, project maintenance, project renewal, and project demolition (refer to **Figure 4**).

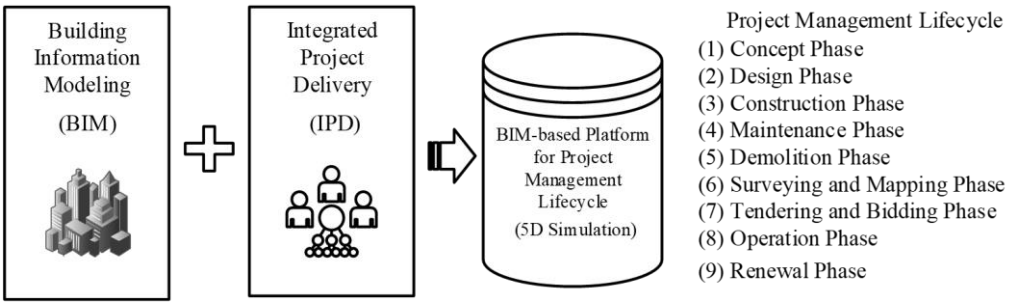

Figure 4. BIM-based IPD platform for project management lifecycle (5D simulation).

To ensure efficient risk management throughout the process, the implementation of collaborative technology in the BIM-based IPD model ensures the precise execution of project milestones and the successful attainment of performance targets (refer to **Figure 5**) (Ma et al., 2014).

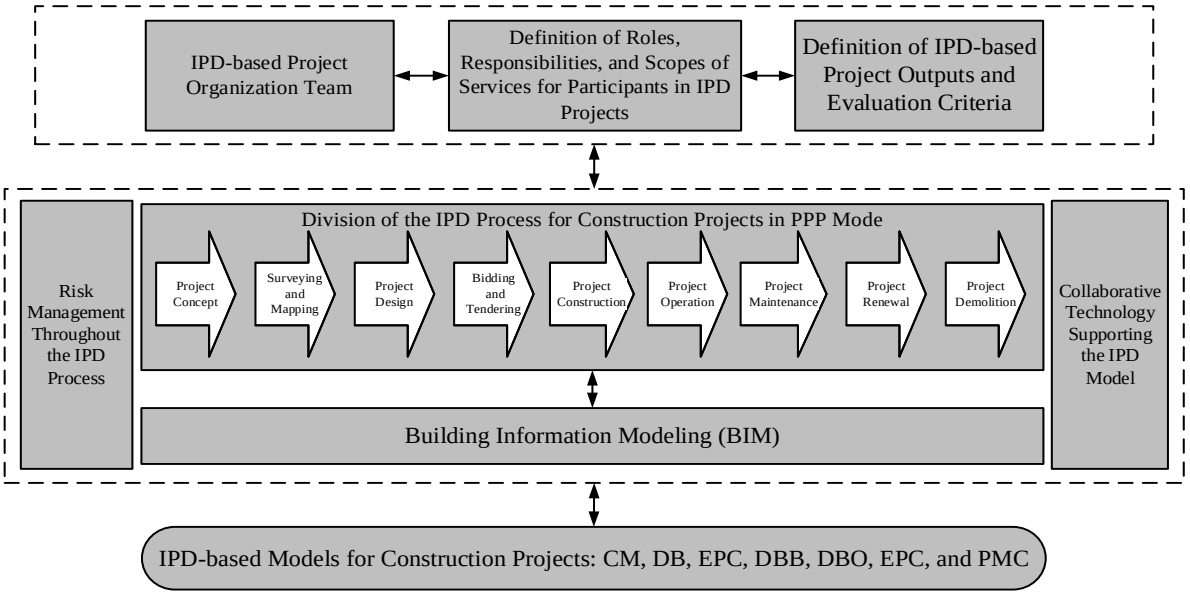

Figure 5. BIM-based IPD collaborative management model for construction projects in PPP mode.

The franchises of characteristic towns in PPP mode apply the BIM-based IPD model to set common objectives with all parties involved. On this basis, they enter multi-party contracts to control and manage the collaborative work of all parties involved through thorough contract preparation. This reduces the probability of

problems during the construction process, ensuring the smooth execution of the project, as illustrated in **Figure 6** (Zhang et al., 2022; Rao and Wang, 2021).

All parties involved shall adhere to the principles of risk sharing, revenue sharing, multi-level collaboration, information transparency, and democratic equality. Additionally, the network communication platform, coupled with the data center, through the data exchange using BIM, assures lean construction management and profit maximization. The framework for the BIM-based IPD collaborative management model for the construction projects in PPP mode is illustrated in **Figure 6**.

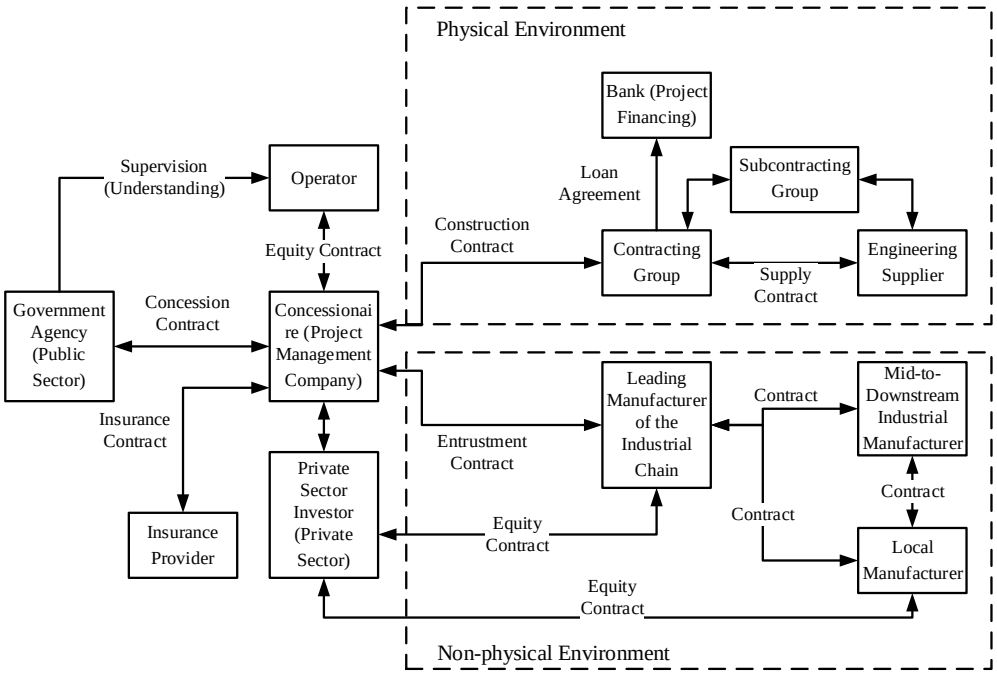

Figure 6. Organizational structure of the characteristic towns in PPP mode.

4.2. Functions of each phase in the PPP project management lifecycle

(1) Organizational structure

In this mode, the members of the organization, led by the owner and the contractor, give significant instructions for the project and manage its entire lifecycle. All parties involved make informed decisions based on common objectives. Additionally, the free flow of information facilitates smooth communication and collaboration among all parties involved.

(2) Contract agreement

All parties involved in sharing common objectives enter a multi-party contract under the IPD model. This contract allocates responsibilities for various aspects of a project, such as its schedule and costs. Sharing both risks and benefits prevents conflicts that may arise among the parties due to delayed or ambiguous information or situations where parties prioritize their interests at the expense of the common benefits. Establishing an appropriate contract in the initial phase mitigates the probability of disputes arising among the parties involved.

(3) Project implementation

One significant difference between the IPD model and traditional models is the early involvement of contractors, major subcontractors, and suppliers in the implementation process. This fosters a strong collaborative environment where all parties involved work closely together, share information transparently, and make decisions jointly. Although it may take longer during the design phase, this model effectively prevents the accumulation of issues that may require rework during the later construction phase. As such, it greatly reduces the duration and cost of the review and construction, ultimately leading to a shorter project timeline.

(4) Technical support

The IPD project relies primarily on different information technologies for information integration. The BIM model serves as an excellent platform for integrating the efforts of all parties involved in the project management lifecycle. The visualization and coordination features of the BIM model can effectively reduce potential issues during the planning, construction, and operation phases. With its assistance, future risks can be predicted, simulated, analyzed, and resolved in advance to prevent unexpected events (Kou, 2020; Zhang, 2017).

5. Discussion

In the advancement of characteristic towns in PPP mode, all parties involved are engaged in the construction, operation, maintenance, and management of various characteristic industries (Wang, 2021; Zhang, 2018).

(1) Effective collaboration and active participation from all parties involved facilitate the seamless exchange of project information.

The characteristic towns in PPP mode differ from those in traditional management models. In traditional models, communication among all parties involved may be hindered by factors such as institutional limitations and management models, leading to an inefficient flow of information (Kou, 2020). The BIM-based IPD model, by contrast, facilitates effective collaboration among all stakeholders and streamlines tasks, thereby mitigating the fragmentation of project information and promoting efficient communication and interaction among all parties involved.

(2) It becomes feasible to coordinate visual and multidimensional planning during the conceptual design phase (Zhao, 2021).

Within a 3D concept model, designers can engage in a more comprehensive design process for the tunnel route. This 3D model enables designers to visually and comprehensively comprehend the physical and non-physical environmental factors of the project.

(3) The utilization of simulation during the design phase significantly enhances the decision-making process by considering local circumstances.

The utilization of BIM technology in visual design and virtual computer design simulation systems facilitates an objective and realistic analysis of the site. Additionally, BIM technology facilitates the analysis of measured parameters and coefficients for energy consumption. The utilization of this technology allows for the dynamic simulation of various environmental conditions, thereby enabling the implementation of design and simulation for an energy-efficient system (Zhou, 2020; Xu et al., 2011).

(4) The implementation of "Internet+" technology during the construction phase proves to be an effective means of supervision.

The BIM-based collaborative management system facilitates the synchronous interaction of data among the various stakeholders involved in the construction process. This system enables the owner, supervisor, and construction team to efficiently access real-time information related to the construction site. This includes connecting all the equipment on the construction site to the information platform, thereby facilitating real-time monitoring of the project and its surroundings using "Internet+" technology. This contributes to achieving efficient project coordination and fostering the adoption of civilized construction practices (Kou, 2020).

(5) Integration of unit information is crucial during the operation and maintenance phase to ensure effective operation and maintenance.

The BIM-based IPD collaborative management system for construction information effectively manages an overwhelming majority of data throughout the construction phase, including information ranging from the design of the construction drawing to its execution (Huang et al., 2021). This greatly simplifies the collaborative management of data resources throughout the various stages of construction, operation, and maintenance. In addition, it effectively integrates the information of accountability units and executing units, thereby facilitating the management of operation and maintenance activities.

The BIM-based IPD collaborative management system specific implementation requirements are as follows:

Implementation requirements:

(1) Modeling and management using BIM software: Use BIM (building information modeling) software tools to create three-dimensional models of the characteristic town, encompassing various disciplines such as architecture, structural engineering, and mechanical and electrical engineering. Ensure the completeness and accuracy of the model data for subsequent collaborative design and decision-making.
(2) Establish a multi-disciplinary collaboration platform: Set up a multi-disciplinary collaboration platform to facilitate real-time communication and collaboration among different professional teams. The platform should have functionalities such as model viewing, revision, approval, and be able to track and manage project progress.
(3) Develop collaborative design processes based on IPD (integrated project delivery): Establish collaborative design processes based on IPD that clearly define task allocation, information sharing, decision-making, and other aspects between different disciplines. Ensure effective interface and coordination among disciplines.
(4) Involve expert consultation and guidance: Invite experts from relevant fields at key stages for consultation and support, such as architects, structural engineers, and mechanical and electrical engineers. Leverage their professional knowledge and experience to resolve technical challenges and management issues.
(5) Promote green design and sustainability: Actively adopt green building technologies and environmentally friendly materials during the construction of the characteristic town to reduce energy consumption and carbon emissions.

Introduce green building assessment systems or certifications to enhance the sustainability and environmental performance of the project.

The BIM-based IPD collaborative management system specific recommendations are as follows:

(1) Develop collaborative design processes based on IPD (integrated project delivery): Create a set of collaborative design processes based on IPD, which clearly defines the allocation of tasks, information sharing, decision-making, and other aspects among different disciplines. This will ensure effective communication and coordination among the various teams.

(2) Involve expert consultation and guidance: Engage experts in relevant fields at key stages for consultation and support. Their professional knowledge and experience can be leveraged to help resolve technical challenges and manage associated issues.

(3) Promote green design and sustainability: Adopt green building technologies and environmentally friendly materials during construction to reduce energy consumption and carbon emissions. Introduce green building assessment systems or certifications to enhance the sustainability of the project.

(4) Define standardized BIM model creation criteria and processes for each discipline, including data formats, precision requirements, coordination procedures, etc. Develop unified modeling guidelines and standards to facilitate coordination and information sharing among disciplines.

(5) Establish a BIM collaboration management platform to facilitate information sharing and collaborative work among disciplines. The platform should have functionalities such as model viewing, modification, approval, and be capable of recording and tracking project progress. Consider adopting mature BIM collaboration management platforms or developing customized solutions tailored to project needs.

6. Conclusion

The current difficulty in developing characteristic towns lies in the inefficiency of supervising and integrating construction and operation information from all parties involved. This gives rise to delays in risk management, failures to promptly halt and rectify out-of-control projects, mistakes in decision-making, and ultimately, detriments to public interests (Liang, 2020; Liang, 2019). This study applies the BIM-based IPD collaborative management model to characteristic towns in PPP mode in a bid to facilitate smooth communication at every phase throughout the project management lifecycle. This significantly reduces time and cost and enhances productivity. Moreover, this model exhibits promising potential for development and contributes greatly to improving construction concepts and constructing high-quality buildings (Jasper et al., 2020).

Furthermore, the current application of collaborative management in China has certain weaknesses. Specifically, challenges do exist with the implementation of collaborative management for characteristic towns in PPP mode, including the absence of preliminary information about local characteristics, a comprehensive legal framework, and standardized industry standards. Additionally, there is limited

knowledge of multidimensional design, the rapid pace of iteration in intelligent information management, and an unclear definition of rights and responsibilities among all parties involved. Nonetheless, the growing influence of "Internet+" and AI technology stimulates the potential for addressing these challenges.

This paper analyzes and constructs a collaborative model to enhance the application of collaborative management technology. And uses the Internet and artificial intelligence technology to integrate and play an advantage with the current AI industry trend to create an opportunity for the development of public construction that can be applied to intelligent capabilities.

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