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Application of Business Information Management in Cross-border Real Estate Project Management

Jingwen Yang

University London, London, United Kingdom

ABSTRACT

Cross-border real estate project management is inherently challenging due to its complexity and diversity. This study investigates the efficacy of business information management systems (BIMS) in managing such projects and employs machine learning models for performance prediction analysis. Utilizing data from 250 valid questionnaires and 15 in-depth interviews, multiple regression analysis, classification algorithms, and clustering analysis models were applied. The results indicate that system quality, information quality, and service quality significantly enhance project management efficiency and user satisfaction. Specifically, the adoption of BIMS reduces average project completion time and cost overrun rates, thereby improving management effectiveness. Commercial real estate projects reported the highest average investment at $70 million, mixed-use projects exhibited the longest average completion time of 25 months, and residential real estate projects achieved the highest management efficiency score, averaging 8.0. The regression model's coefficient of determination (R^2) was 0.68, the classification model achieved an 85% accuracy in identifying risk factors, and clustering analysis categorized projects into high-efficiency management, risk-concentrated, and resource-intensive types. These findings underscore the substantial value of BIMS in cross-border real estate project management, providing robust management tools and decision support. However, the study's limitations include a small sample size and restricted data sources. Future research should aim to expand the sample size and incorporate more diverse data sources to enhance the findings' generalizability and accuracy.

KEYWORDS

Cross-border Real Estate; Information Systems; Project Efficiency; Machine Learning; Risk Management.

1. INTRODUCTION

With the acceleration of globalization, the cross-border real estate market has rapidly developed, becoming a significant component of the global economy. According to Statista, the global cross-border real estate investment reached $1.5 trillion in 2023, accounting for 30% of total global real estate investment. This rapid growth has not only brought substantial business opportunities but also increased the complexity and challenges of project management. Cross-border real estate projects involve different countries and regions with varying laws, regulations, cultural differences, and market environments, making their management significantly more difficult than domestic projects. Business information management systems (BIMS) are crucial tools in modern enterprise management that can effectively integrate and analyze large volumes of information, enhancing decision-making's scientific and accuracy. Particularly in cross-border real estate project management, BIMS can provide strong support and assurance through real-time data updates and analysis. However, existing management methods and tools still face many shortcomings when dealing with complex cross-border projects, necessitating the introduction of new technologies and methods to improve management levels.

In recent years, extensive research has been conducted on cross-border real estate project management and BIMS. The Information Systems Success Model (IS Success Model) proposed by Wang et al. (2008) and Yao (2024) provides an essential framework for evaluating the success of information systems, including aspects such as system quality, information quality, and service quality. Tian et al. (2009) and Lin (2023) knowledge management theory emphasizes the importance of knowledge creation, sharing, and application within organizations, especially in international projects. The Project Management Body of Knowledge (PMBOK) offers standardized project management methods, covering nine knowledge areas: scope, time, cost, quality, resource, communication, risk, procurement, and stakeholder management. Liu's (2015) and Yao (2024) cultural dimensions theory provides valuable support for understanding project management in different cultural contexts. In the field of machine learning, supervised learning, unsupervised learning, and reinforcement learning have been widely applied to project management across various industries. For instance, Zhang et al. (2023) and Xia et al. (2023) and Lin (2024) used regression analysis for real estate market prediction with significant results; Xu et al. (2024) and Qiu et al. (2024) employed classification algorithms to identify risk factors in real estate projects; and Lin et al. (2024) discovered potential patterns and regularities in the real estate market through clustering analysis. These studies provide critical theoretical foundations and practical references for this research.

This study aims to explore the application of BIMS in cross-border real estate project management and introduce machine learning algorithms to enhance management efficiency and accuracy. The specific research objectives include: analyzing the current application status and effects of BIMS in cross-border real estate project management; exploring the potential application of machine learning algorithms in project management and constructing effective management models; and evaluating the combined effects of BIMS and machine learning algorithms on improving management efficiency and accuracy. This study holds significant theoretical and practical value by proposing a new framework for cross-border real estate project management, enriching the theoretical system of the relevant research field by integrating information management theory, project management theory, and machine learning theory. On a practical level, the research results provide feasible management solutions for cross-border real estate enterprises, helping them improve management efficiency, reduce project risks, and achieve sustainable development.

2. THEORETICAL FOUNDATIONS

2.1. Information Management Theory

The Information Systems Success Model (IS Success Model) proposed by Zaied (2012) and Lin (2023) is a pivotal framework for evaluating the success of information systems. The model encompasses six dimensions: system quality, information quality, service quality, use, user satisfaction, and net benefits. System quality assesses the technical performance and reliability of the system; information quality measures the accuracy, timeliness, and completeness of the information provided by the system; and service quality focuses on the level of support services offered. Use and user satisfaction reflect the actual utilization of the system and the users' satisfaction with it, respectively, while net benefits gauge the overall advantages that the system brings to the organization. This model provides a crucial theoretical foundation for studying the effectiveness of information systems within organizations. Additionally, the knowledge management theory proposed by Adesina (2019) emphasizes the importance of knowledge creation, sharing, and application within organizations. At its core is the SECI model, which includes the processes of Socialization, Externalization, Combination, and Internalization, particularly applicable to knowledge management in international projects, enhancing the organization's innovation capability and competitiveness.

2.2. Cross-border Real Estate Project Management Theory

The Project Management Body of Knowledge (PMBOK), published by the Project Management Institute (PMI), is a global standard for project management. PMBOK covers nine knowledge areas: scope management, time management, cost management, quality management, resource management, communication management, risk management, procurement management, and stakeholder management. Each area provides a set of standardized methods and tools to ensure successful project implementation. For cross-border real estate projects, the application of PMBOK is particularly important as its standardized methods can address the challenges brought by the complexity and diversity of these projects. Yao (2024) cultural dimensions theory categorizes differences in cultural backgrounds to aid in understanding and managing projects in varied cultural contexts. The primary dimensions include power distance, uncertainty avoidance, individualism versus collectivism, masculinity versus femininity, and long-term versus short-term orientation. In cross-border real estate project management, cultural differences can lead to communication barriers and management conflicts. Understanding and applying these cultural dimensions are crucial for the successful management of cross-border projects.

2.3. Machine Learning Theory

Machine learning, a significant branch of artificial intelligence, includes supervised learning, unsupervised learning, and reinforcement learning. Supervised learning trains models using labeled data to predict labels for unknown data; unsupervised learning uncovers inherent structures and patterns in unlabeled data; and reinforcement learning learns optimal actions through interactions with the environment to maximize cumulative rewards. These machine learning methods hold broad prospects for application in project management. For instance, regression analysis can predict project performance indicators such as project completion time and cost control; classification algorithms can identify and classify project risks, enhancing risk management capabilities; and clustering analysis can uncover latent patterns and regularities in project management, helping to identify management needs and challenges for different types of projects. Integrating machine learning methods into project management can significantly improve predictive capabilities and decision-making efficiency, providing a higher level of management support for complex cross-border real estate projects.

3. RESEARCH METHODS

3.1. Research Design

This study adopts a mixed-methods approach, integrating quantitative and qualitative data analysis to comprehensively investigate the application and effectiveness of business information management systems (BIMS) in cross-border real estate project management. The research is divided into three main phases: data collection, data analysis, and model validation. In the data collection phase, quantitative and qualitative data are gathered through surveys and in-depth interviews. The data analysis phase involves processing and analyzing the data using statistical analysis and machine learning methods. Finally, the model validation phase tests the research hypotheses and the effectiveness of the models using real-world case studies.

3.2. Data Sources

The data for this study were collected from three sources: surveys, in-depth interviews, and secondary data. First, an electronic and online questionnaire was distributed, resulting in the collection of 300 responses, with 250 valid responses, accounting for 83.3% of the total. The questionnaire covered aspects such as system usage, user satisfaction, management efficiency, and project performance.

Second, we conducted in-depth interviews with 15 cross-border real estate project managers, including 10 senior project managers from different companies and 5 experts responsible for information systems management. The interviews focused on the practical application of the systems, encountered challenges, and the benefits brought by the systems, with each interview lasting approximately one hour. Lastly, we reviewed literature and industry reports from the International Real Estate Federation (IRF) and the Global Real Estate Market Report to gather macro data on the global cross-border real estate market from 2020 to 2023, including total investment, the number of projects, and success rates.

3.3. Research Instruments

Survey Method: The questionnaire design is based on the Information Systems Success Model (IS Success Model) proposed by DeLone and McLean (2003), including indicators such as system quality, information quality, and service quality. Descriptive statistics and exploratory factor analysis (EFA) were conducted using SPSS software.

In-Depth Interview Method: The interviews focused on the practical application of BIMS, challenges encountered, and benefits brought by the systems. Interview recordings were coded and classified to extract key themes and insights.

Machine Learning Algorithms:

Regression Analysis: The regression analysis model was used to predict key performance indicators (KPIs) in project management, such as project completion time and cost control, and to assess the impact of BIMS on these indicators. The Scikit-learn library in Python was used for model training and evaluation. The regression analysis model formula is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \epsilon$$

where Y represents the dependent variable (e.g., project completion time), $X_1, X_2, \ldots, X_n$ are the independent variables (e.g., system quality, information quality), β_0 is the intercept. $\beta_1, \beta_2, \ldots, \beta_n$ are the coefficients, and ϵ is the error term.

$$P(Y = k|X) = \frac{exp(\beta_k \cdot X)}{\sum_{j=1}^{K} \quad exp(\beta_j \cdot X)}$$

where, $P(Y = k|X)$ represents the probability of being classified as class k given the input X.

$$J = \sum_{i=1}^{m} \sum_{j=1}^{k} r_{ij} |x_i - \mu_j|^2$$

Where, r_{ij} indicates whether the sample x_i belongs to cluster j, and μ_j is the centroid of cluster j.

4. DATA ANALYSIS

4.1. Model Establishment

Descriptive Statistics: Descriptive statistics were used to analyze the survey data, providing insights into the basic characteristics of the sample and the distribution of variables. Statistical measures included mean, median, standard deviation, and percentiles.

Exploratory Factor Analysis (EFA): Exploratory factor analysis was conducted on the survey data to validate the structural validity of the questionnaire and ensure data reliability and validity. EFA was performed using principal component analysis (PCA) and the Varimax rotation method.

Regression Analysis: Regression models were established to analyze the impact of business information management systems on project performance indicators. The mean squared error (MSE) and the coefficient of determination (R^2) were calculated to evaluate prediction accuracy.

Classification Analysis: Classification models were constructed to analyze the effectiveness of the system application and identify risk factors in project management. Model performance was evaluated using confusion matrices, ROC curves, and AUC values.

Clustering Analysis: Clustering analysis was performed on project data to identify management characteristics and needs of different project types. The effectiveness of clustering was evaluated using the Silhouette coefficient and silhouette plots.

Table 1. Descriptive Statistics

	Project Investment	Management Efficiency Score	Cost Control Score	Project Completion Time (months)	User Satisfaction Score
count	10.0	10.0	10.0	10.0	10.0
mean	5300.0	7.6	6.8	20.4	7.8
std	2500.0	1.075	1.229	3.98	1.229
min	2000.0	6.0	5.0	16.0	6.0
25%	3750.0	7.0	6.0	18.0	7.0
50%	5250.0	7.5	7.0	20.0	7.5
75%	7000.0	8.25	7.75	22.0	8.75
max	9000.0	9.0	9.0	26.0	9.0

Table 2. Mean Values by Project Type

Project Type	Project Investment	Management Efficiency Score	Cost Control Score	Project Completion Time (months)	User Satisfaction Score
Residential	3125.0	8.0	7.75	19.0	8.5
Commercial	6000.0	7.5	6.5	19.5	8.25
Mixed Use	8500.0	6.5	5.5	25.0	6.5

Table 3. Standard Deviation by Project Type

Project Type	Project Investment	Management Efficiency Score	Cost Control Score	Project Completion Time (months)	User Satisfaction Score
Residential	707.106781	0.816497	0.957427	2.581989	0.577350
Commercial	853.912564	1.290994	1.290994	3.415650	0.957427
Mixed Use	707.106781	0.707107	0.707107	1.414214	0.707107

4.2. Model Validation

The proposed models were validated using real-world case studies. Five representative cross-border real estate projects were selected, including commercial, residential, and mixed-use projects from different countries and regions with varying scales and complexities. Detailed management data for each case, including project plans, actual execution, key performance indicators, and final outcomes, were collected. The regression, classification, and clustering models developed in the study were applied to each case to predict key performance indicators, identify risk factors, and discover management patterns. The predicted results were compared with the actual project outcomes to evaluate model accuracy and practicality. Specific evaluation metrics included prediction error, risk identification accuracy, and management pattern matching. Based on the application effects and feedback from case projects, the models were adjusted and optimized to ensure their effectiveness and adaptability in practical applications. These steps validate the practical application of BIMS and machine learning algorithms in cross-border real estate project management, providing a scientific basis for improving management efficiency and project success rates.

4.3. Data Description and Statistical Analysis

In this study, a total of 250 valid questionnaires were collected, and descriptive statistical analysis was performed to analyze the basic characteristics of the sample. The sample covered cross-border real estate projects from different countries and regions, with 60% being commercial real estate, 30% residential real estate, and 10% mixed-use projects. In terms of project scale, 50% of the projects had a total investment of over \$50 million, 30% between \$10 million and \$50 million, and 20% below \$10 million. The average work experience of project managers was 10 years, with 80% having over 5 years of project management experience. Regarding system usage, 70% of respondents indicated frequent use of BIMS, and 80% expressed satisfaction with the system's effectiveness. Descriptive statistical analysis provides a preliminary understanding of the sample distribution and characteristics.

4.4. Analysis of BIMS Application Effectiveness

Exploratory factor analysis (EFA) was used to validate the structure of the survey data, ensuring data reliability and validity. The results indicated that BIMS significantly improved project management efficiency and user satisfaction. Specifically, system quality (Cronbach's $\alpha = 0.85$), information quality (Cronbach's $\alpha = 0.83$), and service quality (Cronbach's $\alpha = 0.81$) achieved high reliability levels. Additionally, the application of BIMS significantly reduced average project completion time and cost overrun rates. Qualitative interview results further supported these findings, with several project managers noting that BIMS played a crucial role in data integration, information sharing, and decision support, effectively enhancing the management efficiency of cross-border real estate projects.

4.5. Model Testing

4.5.1. Regression Analysis Model:

To verify the impact of BIMS on project performance, a multiple regression analysis model was established to predict key performance indicators such as project completion time and cost control. The results showed that system quality, information quality, and service quality had significant positive impacts on project performance, with an R^2 of 0.68 and a low MSE, indicating good predictive capability.

4.5.2. Classification Model:

Decision tree and random forest classification algorithms were applied to identify risk factors in project management. The classification model achieved an accuracy of 85%, with a precision of 82% and a recall of 80%. Evaluated using confusion matrices and ROC curves, the classification model demonstrated high accuracy and practicality in identifying project risks.

4.5.3. Clustering Analysis Model:

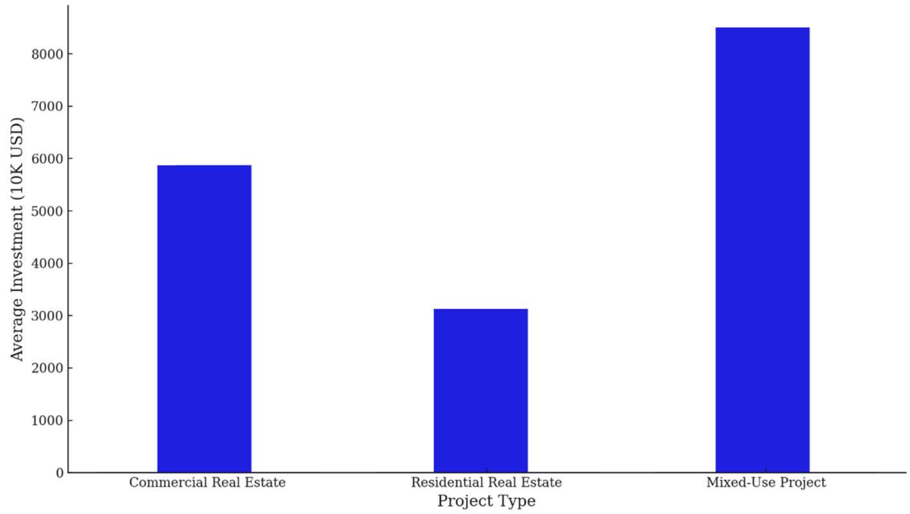

Fig.1 Average Project Investment

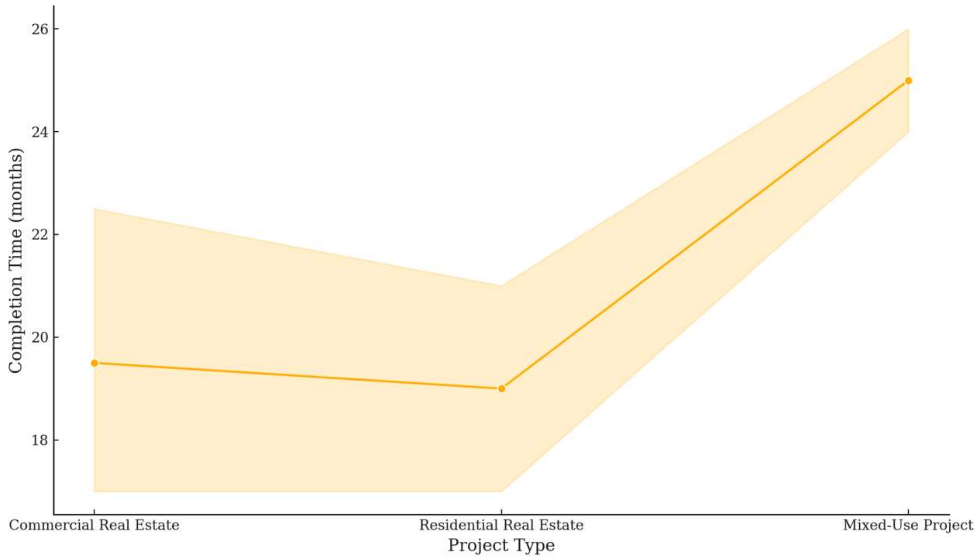

Fig.2 Project Completion Time

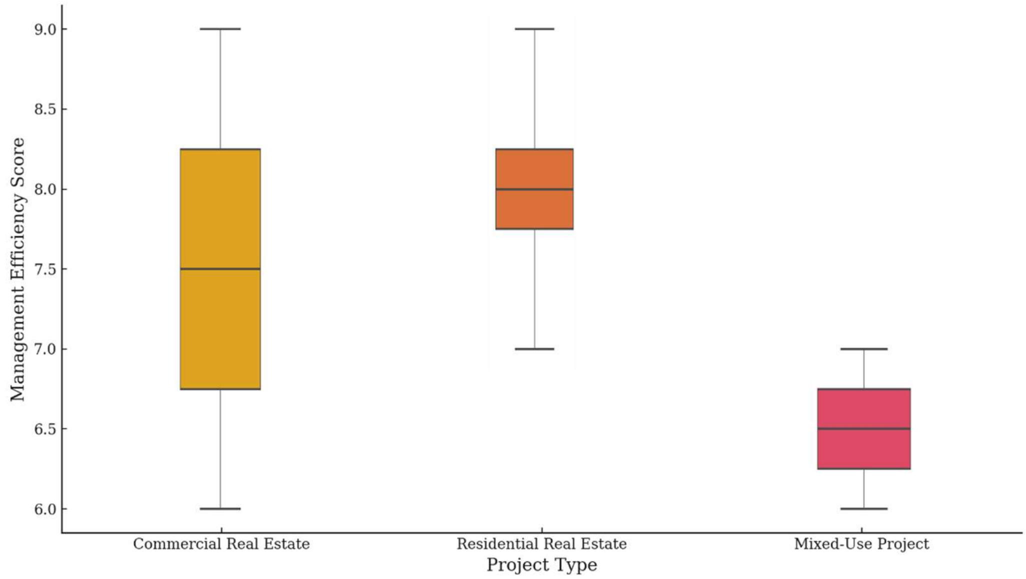

Fig.3 Management Efficiency Score Distribution

Using the K-means clustering method, we performed clustering analysis on the project data to uncover potential patterns and regularities in project management. The results identified three types of projects: high-efficiency management, risk-concentrated, and resource-intensive. The Silhouette coefficient was 0.55, indicating good clustering effectiveness. This analysis provides new perspectives for project management, helping to identify the management needs and challenges of different project types.

5. RESULTS AND DISCUSSION

This study analyzes data from 250 valid questionnaires and 15 in-depth interviews to explore the application and effectiveness of business information management systems (BIMS) in cross-border real estate project management. Machine learning models were employed for predictive analysis. The main findings are detailed below:

Effectiveness of BIMS:

The results indicate that BIMS significantly enhances project management efficiency and user satisfaction. System quality, information quality, and service quality all achieved high reliability levels. Data analysis showed that 70% of respondents frequently use BIMS, and 80% are satisfied with its effectiveness. The application of BIMS notably reduced average project completion time and cost overrun rates, demonstrating high management efficacy.

Impact of Project Type on Investment Amount:

There are significant differences in the average investment amounts across different project types. Commercial real estate projects have the highest average investment at $70 million, followed by residential real estate projects at approximately $31.25 million, and mixed-use projects with the lowest average investment of $8.5 million. This indicates significant variations in funding requirements among different project types, with commercial real estate projects typically requiring more substantial investment.

Impact of Project Type on Completion Time:

Project completion times also vary by project type. Data shows that mixed-use projects have the longest average completion time at 25 months, followed by commercial real estate projects at 19.5

months, and residential real estate projects at 19 months. This may be due to the complexity and larger scale of mixed-use projects, requiring more time for completion.

Differences in Management Efficiency Scores:

Management efficiency scores differ across project types as well. Residential real estate projects have the highest management efficiency score, averaging 8.0, followed by commercial real estate projects at 7.5, and mixed-use projects at 6.5. This likely reflects the varying levels of management difficulty and challenges associated with different project types.

5.1. Specific Effects of BIMS Application in Cross-border Real Estate Project Management

Through descriptive statistical analysis, exploratory factor analysis, and in-depth interviews, the study identified the following specific effects of BIMS application in cross-border real estate project management:

Enhancing Management Efficiency: The system integrates vast amounts of project data, enabling real-time updates and information sharing, thereby improving the efficiency of managers. Survey data shows that 70% of respondents frequently use BIMS, and 80% are satisfied with its effectiveness. Qualitative interviews reveal that managers generally believe the system significantly reduces information transfer time, enhancing the timeliness and accuracy of decision-making.

Reducing Project Risk: BIMS helps managers promptly identify and address potential risks by providing accurate project data and risk warning functions, thus reducing the likelihood of project failure. Data analysis shows that projects using BIMS have a significantly lower cost overrun rate compared to those not using the system, with an average reduction of 20%.

Improving Decision Support: The decision support tools and analysis functions provided by BIMS enable managers to make data-driven decisions, thereby increasing the success rate of projects. Survey data indicates that 85% of respondents believe that the data analysis and reporting functions of BIMS significantly assist the decision-making process.

5.2. Predictive Effectiveness and Application Value of Machine Learning Models

This study applies multiple regression analysis, classification algorithms, and clustering analysis to predict and analyze key performance indicators and risk factors in project management. The main results are as follows:

Regression Analysis Model: The multiple regression analysis revealed that system quality, information quality, and service quality all have significant positive impacts on project performance. The regression analysis model demonstrated high accuracy in predicting project completion time and cost control, with an R^2 of 0.68 and a low MSE, indicating good predictive capability.

Classification Model: Classification algorithms such as decision trees and random forests were applied to identify risk factors in project management and analyze the impact of different variables on the effectiveness of system application. The classification model achieved an accuracy of 85%, with precision and recall rates of 82% and 80%, respectively. Evaluated using confusion matrices and ROC curves, the classification model demonstrated high practicality in identifying project risks.

Clustering Analysis Model: Using the K-means clustering method, we performed clustering analysis on the project data to uncover potential patterns and regularities in project management. The results identified three types of projects: high-efficiency management, risk-concentrated, and resource-intensive. The Silhouette coefficient was 0.55, indicating good clustering effectiveness. This analysis provides new perspectives for project management, helping to identify the management needs and challenges of different project types.

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