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MODELING AND INFORMATION TECHNOLOGIES IN CONSTRUCTION

**BIM-BASED ORGANIZATIONAL AND TECHNOLOGICAL MODERNIZATION OF
CONSTRUCTION LOGISTICS: A CASE STUDY OF ARMENIA**

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Construction projects increasingly face logistical inefficiencies affecting schedule reliability, cost control, and resource utilization, particularly under supply variability and spatial constraints. Construction logistics includes procurement planning, transportation, storage, on-site handling, scheduling, and information-flow coordination. Construction logistics is examined as an integrated component of organizational and technological construction management, while Building Information Modeling (BIM) is considered a digital platform for coordinating and controlling logistics processes. A comparative case study of two large-scale residential projects implemented by the same developer at different lifecycle stages in the Republic of Armenia was conducted using descriptive indicators of delivery lead times, emergency interventions, storage dependency, and work disruptions. The results indicate that delayed BIM implementation is associated with greater logistics variability, reliance on emergency procurement, and logistics-driven work interruptions. Early BIM-based logistics integration improves predictability, reduces reactive interventions, and enhances process controllability. A BIM-based organizational and technological framework for improving construction logistics performance is proposed.

Keywords: *construction logistics, Building Information Modeling((BIM), organizational and technological systems, logistics controllability, digital construction*

Introduction

Construction logistics has become a critical factor influencing project performance in modern construction practice. In the context of the Republic of Armenia, logistics-related challenges are particularly pronounced due to the dependence on imported construction materials, limited local manufacturing capacity, and the exposure of supply chains to external geopolitical, infrastructural, and climatic factors. Construction logistics includes procurement planning, transportation, storage, on-site material handling, scheduling, and coordination of information flows between project participants [1-3]. Insufficient integration of these processes may result in schedule delays, cost escalation, material losses, and reduced predictability of construction outcomes [1, 3].

These challenges are especially relevant for large-scale residential developments characterized by high material intensity, dense urban locations, and limited on-site storage capacity. In Armenia, supply lead times are subject to significant variability caused by production constraints, border conditions, changes in transportation routes, and external disruptions. As a result, logistics-related risks frequently propagate across construction schedules, procurement plans, and resource allocation processes.

Building Information Modeling (BIM) has been widely adopted as a digital approach supporting information integration, coordination, visualization, construction planning, and decision-making throughout

the project lifecycle [2, 4]. However, in many practical applications, BIM is introduced at later project stages and used primarily for visualization, design coordination, and clash detection, which limits its potential contribution to proactive logistics planning and control [5, 6].

Although BIM applications, construction logistics, and digital supply-chain integration have been extensively studied, limited empirical attention has been given to the influence of BIM implementation timing on logistics controllability within import-dependent construction environments. This issue is particularly relevant where external supply-chain variability increases the importance of organizational and technological coordination. This study addresses the identified gap through a comparative analysis of two residential construction projects implemented by the same developer at different lifecycle stages. Construction logistics is examined as an integrated element of organizational and technological construction management, and a BIM-based framework for improving logistics planning and control is proposed.

Materials and Methods

Construction logistics has evolved from a narrowly defined function focused on material delivery into an integrated process encompassing procurement planning, transportation, storage, on-site handling, construction sequencing, and coordination of information flows among project stakeholders. Construction supply-chain research indicates that performance losses frequently originate from fragmentation between supply-chain decisions and site production requirements. Consequently, logistics inefficiencies are increasingly interpreted as coordination and planning problems rather than solely as transportation constraints [1, 3].

Recent research highlights the role of Building Information Modeling (BIM) in improving logistics controllability through information integration, material tracking, procurement planning, and coordinated decision-making [2, 4]. In this context, a distinction should be made between physical supply lead times and logistics controllability. Manufacturing capacity, transportation routes, customs procedures, and external disruptions determine the physical duration of supply, whereas BIM-supported planning may improve the predictability, traceability, and coordination of logistics processes without necessarily shortening delivery durations [2, 3].

The effectiveness of BIM-supported management depends not only on the availability of digital models but also on the timing, scope, and organizational maturity of implementation [4-6]. Limited applications, including design coordination, clash detection, quantity verification, and selective 4D planning, may improve information visibility and reduce selected coordination problems. Nevertheless, partial or late-stage implementation restricts the integration of procurement, logistics, and construction planning and therefore limits the potential for proactive control.

Research on BIM-enabled 4D planning and site logistics demonstrates that integrated models can support construction-sequence visualization, workspace planning, material-flow coordination, and synchronization of deliveries with site activities [7, 8]. Site-logistics studies also identify planning and forecasting, material movement, technology and equipment, site conditions, and material protection as factors affecting resource use, rework, material damage, and construction waste [3]. At the supply-chain level, the development of digital-twin concepts extends BIM-based coordination by linking digital representations with updated information from physical processes, thereby supporting situational awareness and feedback-based control [9-11]. Bibliometric studies confirm increasing research interest in the integration of BIM, the Internet of Things, and digital twins across construction lifecycle processes [12].

Despite the growing literature on BIM, digital twins, construction logistics, and supply-chain coordination, limited empirical attention has been given to the influence of BIM implementation timing on logistics controllability in import-dependent construction environments. This gap is addressed through a comparative analysis of two residential construction projects implemented by the same developer at different lifecycle stages. The first project represents late and partial BIM implementation, whereas the second incorporates BIM-based logistics planning from an earlier project stage.

Research Method and Framework

A qualitative comparative case study methodology supported by descriptive quantitative indicators is adopted. Two large-scale residential construction projects located in the Republic of Armenia and executed by the same developer were selected to control for organizational, regulatory, and market conditions while allowing comparison of logistics performance at different project lifecycle stages.

Construction logistics is analyzed as an integrated subsystem of organizational and technological construction management. Based on the analysis, a BIM-based logistics framework is proposed, consisting of organizational, process, information, and control layers. BIM is considered an enabling platform supporting coordination, monitoring, and adaptive control of logistics processes.

The organizational layer defines roles, responsibilities, and decision-making authority related to logistics planning and execution. The process layer integrates logistics activities with construction sequencing and procurement schedules. The information layer is enabled through BIM and provides a shared environment for spatial, temporal, and resource-related data. The control layer supports monitoring and feedback mechanisms that enable proactive response to logistics risks.

The quantitative indicators used in the comparative analysis are descriptive in nature and are derived from site records, procurement logs, planning documentation, and project management reports. These indicators are intended to support a structured comparative assessment of logistics performance and controllability rather than statistical generalization. The methodological focus of the study is on organizational and technological differences between the cases rather than numerical optimization.

Case Study Description

The empirical analysis is based on two large-scale residential construction projects located in the Republic of Armenia and implemented within the same regulatory, economic, and supply chain environment, enabling a controlled comparison of logistics performance across different project lifecycle stages.

Both projects are characterized by high material intensity, strong dependence on imported construction and finishing materials, limited on-site storage capacity, and complex coordination requirements among designers, procurement teams, and construction sites.

The first project represents a late-stage development undergoing intensive finishing works. Logistics planning evolved reactively in response to construction pressures and frequent design-related changes. BIM was introduced at a relatively late stage and used primarily for coordination discussions and selective quantity verification.

The second project represents an early-stage development where logistics planning and BIM integration were initiated during the design phase. Organizational structures, procurement strategies, and information

workflows were defined in advance, informed by lessons learned from the first project and supported by BIM-based planning principles.

In both Armenian projects, physical supply lead times are primarily driven by import dependency and external conditions; therefore, the expected improvement in the second project is not a reduction of delivery durations but enhanced logistics controllability through synchronized planning, scheduling, storage strategy, and information coordination.

Results and Discussion

The comparative analysis demonstrates substantial differences in logistics performance and controllability attributable to the timing and depth of BIM-supported organizational and technological integration. Although both projects operate within the same national and regulatory context, their logistics outcomes differ due to differences in planning maturity and digital integration (fig.).



Fig. Conceptual representation of BIM-based logistics integration and its impact on construction process controllability

Delayed logistics integration in the late-stage project resulted in fragmented coordination, reactive decision-making, frequent emergency procurement actions, and prolonged reliance on external storage facilities. From a management perspective, BIM-supported logistics planning shifts decision-making from reactive responses toward anticipatory coordination based on shared and timely information. This transition enhances process controllability by enabling earlier identification of logistics risks and more informed managerial interventions. Conversely, early-stage BIM-supported logistics planning in the second project enables improved alignment between procurement schedules, construction sequencing, and storage planning (table).

Table

Quantitative comparison of logistics performance indicators

Logistics performance indicator	Metric	Project 1 (late-stage project)	Project 2 (early-stage / expected)
Local supply lead time	Working days	3...10	3...10
Imported supply lead time	Weeks	3...25	3...25
Deliveries exceeding planned lead time	% of orders	~50	<25
Emergency logistics interventions	% of orders	~10	<3
Route changes due to external factors	% of deliveries	~3	Minimal
Materials stored externally	% of total materials	25...30	<15
External storage duration	Months	3...9+	≤2...3
Logistics-driven work stoppages	Duration	1...3 weeks	Rare / avoided
Logistics decisions supported by BIM	%	~20...30	>60 (benchmark-based)

Figure illustrates the conceptual relationship between BIM-based logistics integration and construction process controllability, while Table 1 summarizes the comparative logistics performance indicators. The results confirm that while physical supply lead times remain externally constrained, organizational and technological modernization substantially improves logistics controllability, schedule reliability, and workflow stability.

Conclusions

Based on the comparative analysis, construction logistics inefficiencies are interpreted as systemic outcomes of fragmented organizational coordination and delayed BIM integration rather than as isolated operational failures. Based on the comparative analysis of two large-scale residential projects in the Republic of Armenia, early integration of BIM-based logistics planning is considered capable of enhancing logistics controllability.

Improved delivery predictability, reduced reliance on emergency procurement, lower external-storage dependency, and greater workflow stability are expected to be supported through early BIM-based logistics integration. While the empirical analysis is grounded in the Armenian construction context, the identified logistics challenges and the proposed framework are applicable to other regions characterized by high import dependency and limited on-site logistics capacity.

The proposed BIM-based organizational and technological framework provides practical guidance for integrating logistics into construction management systems and supports more predictable and resilient project execution. Future research may extend this work through longitudinal studies and integration of real-time digital monitoring technologies. Based on the findings, the digital transformation of construction logistics should be approached as an organizational and technological change process rather than as a software-driven initiative, particularly in environments characterized by high supply-chain variability.

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**ՇԻՆԱՐԱՐԱԿԱՆ ԼՈՂԻՍՏԻԿԱՅԻ ԿԱԶՄԱԿԵՐՊՉԱՏԵԽՆՈԼՈԳԻԱԿԱՆ ԱՐԴԻԱԿԱՆԱՑՈՒՄԸ
BIM-Ի ԿԻՐԱՌՄԱՄԲ. ՈՒՍՈՒՄՆԱՍԻՐՈՒԹՅՈՒՆ ՀԱՅԱՍՏԱՆԻ ՕՐԻՆԱԿՈՎ**

Հերմինե Ալբերտի Աղաջանյան, Սաթենիկ Մեյրանի Հայրապետյան՝

Ճարտարապետության և շինարարության Հայաստանի ազգային համալսարան, ք. Երևան, ՀՀ

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Շինարարական նախագծերը հաճախ բախվում են լոգիստիկ անարդյունավետության, որը բացասաբար է ազդում ժամանակացույցի հուսալիության, ծախսերի վերահսկման և ռեսուրսների օգտագործման վրա՝ հատկապես մատակարարման փոփոխականության և տարածական սահմանափակումների պայմաններում: Շինարարական լոգիստիկան ներառում է գնումների պլանավորումը, փոխադրումը, պահեստավորումը, ներշինհրապարակային տեղաշարժը, աշխատանքների ժամանակացույցը և տեղեկատվական հոսքերի համակարգումը: Հետազոտությունում

շինարարական լոգիստիկական դիտարկվում է որպես կազմակերպչատեխնոլոգիական կառավարման բաղադրիչ, իսկ շենքերի տեղեկատվական մոդելավորումը (BIM)՝ որպես լոգիստիկ գործընթացների համակարգման և վերահսկման թվային հարթակ: Համեմատական մեթոդով ուսումնասիրվել են Հայաստանի Հանրապետությունում նույն կառուցապատողի կողմից իրականացվող և կենսացիկլի տարբեր փուլերում գտնվող երկու խոշորածավալ բնակելի նախագծեր: Վերլուծվել են մատակարարման ժամկետները, հրատապ միջամտությունները, պահեստավորումից կախվածությունը և աշխատանքների ընդհատումները: Արդյունքները ցույց են տալիս, որ BIM-ի ուշ ներդրումը կապված է լոգիստիկ փոփոխականության, հրատապ գնումների և աշխատանքների ընդհատումների հետ, մինչդեռ վաղ ինտեգրումը բարձրացնում է գործընթացների կանխատեսելիությունն ու կառավարելիությունը: Առաջարկվել է BIM-ի վրա հիմնված լոգիստիկայի կազմակերպչատեխնոլոգիական համակարգ:

Բանալի բառեր. շինարարական լոգիստիկա, շենքերի տեղեկատվական մոդելավորում (BIM), կազմակերպչատեխնոլոգիական համակարգեր, լոգիստիկայի կառավարելիություն, թվային շինարարություն

ОРГАНИЗАЦИОННО-ТЕХНОЛОГИЧЕСКАЯ МОДЕРНИЗАЦИЯ СТРОИТЕЛЬНОЙ ЛОГИСТИКИ НА ОСНОВЕ BIM: ИССЛЕДОВАНИЕ НА ПРИМЕРЕ АРМЕНИИ

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Строительные проекты часто сталкиваются с неэффективностью логистических процессов, отрицательно влияющих на надежность графиков, контроль затрат и использование ресурсов, особенно в условиях нестабильности поставок и пространственных ограничений. Строительная логистика включает планирование закупок, транспортировку, хранение, внутриплощадочное перемещение, календарное планирование и координацию информационных потоков. В исследовании строительная логистика рассматривается как компонент организационно-технологического управления, а информационное моделирование зданий (BIM) — как цифровая платформа координации и контроля логистических процессов. Сравнительным методом исследованы два крупномасштабных жилых проекта, реализуемых одним застройщиком в Республике Армения и находящихся на разных этапах жизненного цикла. Проанализированы сроки поставок, экстренные вмешательства, зависимость от складирования и перерывы в работах. Результаты показывают, что позднее внедрение BIM связано с повышенной вариативностью логистики, экстренными закупками и нарушениями производственного процесса. Ранняя интеграция BIM повышает предсказуемость и управляемость логистических процессов. Предложена организационно-технологическая система строительной логистики на основе BIM.

Ключевые слова: строительная логистика, информационное моделирование зданий (BIM), организационно-технологические системы, управляемость логистики, цифровое строительство

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