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국내학술발표

게임 엔진을 사용한 모듈 건물 생산의  
이산 사건 시뮬레이션을 위한 임시  
프레임워크  
- 한국CDE학회 2024 동계학술대회 -

2024.11.

과 제 명	인공지능 기반의 건축설계 자동화 기술개발		
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해당연도(4차년)	2024. 01 . 01 - 2024. 12 . 31(1년)		
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세 부 과 제 명	3-A	지능형 설계적법성 평가 및 건축행정 서비스 지원 기술개발	
공 동 연 구 기 관	경희대학교 산학협력단, (주)코스팩이노랩		
연 구 기 관	경희대학교 산학협력단	연구책임자	김인한



# 한국CDE학회 2024 동계학술대회

2024 Winter Conference of Society for  
Computational Design and Engineering

**P R O C E E D I N G S**

**AI시대의 CDE:  
새로운 프론티어를  
향한 탐험**

**2024.  
1. 29|월 ~ 2. 1|목**  
**휘닉스 평창**(강원도 평창군)

| 주최 사단법인 한국CDE학회

| 후원 **KC-ST** **GWTO** 강원도관광재단  
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# Program

29 (Mon)	Time	Room	A 포레스트홀(1F)	B 팀버홀 I	C 팀버홀 II	D 아젠다 I	E 아젠다 II	F 아젠다III	
	16:00-18:00		[AI시대의 CDE: 새로운 프론티어를 향한 탐험] 모색을 위한 전문가 간담회						🔒 좌장: 허태상 <sup>*)</sup>
	1) 16:00-19:00		센서 데이터 기반 인공지능과 ROM 융합형 예지보전 기술개발						

30 (Tue)	08:30-09:00	등록						
	09:00-10:20	<b>Session 1</b> IoT/AI Applications 1	<b>Session 2</b> Smart Manufacturing 1		<b>Session 3</b> Ship & Ocean Engineering 1	<b>Session 4</b> [기획] 가상공간 활용 및 디자인	<b>Session 5</b> [기획] AI 기반 가스·오일 플랜트 운영·유지관리 핵심기술 개발	
		좌장: 김형중	좌장: 윤경호		좌장: 이혜원	좌장: 차승현	좌장: 이재현	
	10:20-10:30	휴식						
	10:30-10:40	Opening Session (포레스트홀, 1F)						
	10:40-11:30	Keynote Speech I (포레스트홀, 1F) / 하정우 센터장(네이버 클라우드)						
	11:30-13:00	휴식				이사회		휴식
	13:00-14:20	<b>Session 6</b> IoT/AI Applications 2	<b>Session 7</b> Smart Manufacturing 2		<b>Session 8</b> Ship & Ocean Engineering 2		가현학술상 심사	
		좌장: 장동원	좌장: 윤경호		좌장: 김기수			
	14:20-14:30	휴식						
	14:30-15:50	<b>Session 9</b> IoT/AI Applications 3	<b>Session 10</b> Smart Manufacturing 3		<b>Session 11</b> Ship & Ocean Engineering 3	<b>Session 12</b> [기획] x-DT, 중소제조기업 맞춤형 디지털트윈 구축 및 운영 기술	<b>Session 13</b> [기획] 설계 품질검토 자동화를 위한 지능형 설계 서비스 보급·활용 기술개발	
		좌장: 김형중	좌장: 박상인		좌장: 이주연	좌장: 김덕영	좌장: 최종식	
	15:50-16:00	휴식						
	16:00-17:20		<b>Session 14</b> Smart Manufacturing 4			<b>Session 15</b> [기획] AI프렌즈 어벤저스 총출동	<b>Session 16</b> [기획] 디지털트윈 기반 스마트제조 응용 기술	
			좌장: 백수정			좌장: 이정원	좌장: 우정엽	
	17:30-19:30	시상식 및 만찬 (포레스트홀, 1F)						

31 (Wed)	08:30-09:00	등록						
	09:00-10:20	<b>Session 17</b> 3D Printing/Building Information Modeling (BIM)	<b>Session 18</b> CAD/CAM/Design Engineering/Nano/ MEMS Applications 1		<b>Session 19</b> Modeling & Simulation 1	<b>Session 20</b> [기획] 산업현장 및 공공시설 내 공기질 향상을 위한 자율주행 기반 스마트 공기정화장치 및 안전관제 서비스 플랫폼 개발	<b>Session 21</b> [기획] 인공지능 학습데이터 품질 평가를 위한 데이터 클리닉	
		좌장: 강경수	좌장: 이진원		좌장: 윤태호	좌장: 강용신	좌장: 오은실	
	10:20-10:30	휴식						
	10:30-11:20	Keynote Speech II (포레스트홀, 1F) / 송시용 상무(LG전자)						
	11:20-12:00	정기총회 (포레스트홀, 1F)						
	12:00-13:10	휴식						
	13:10-14:30	<b>Session 22</b> Machine Learning 1	<b>Session 23</b> CAD/CAM/Design Engineering/Nano/ MEMS Applications 2	<b>Session 24</b> Optimization	<b>Session 25</b> Modeling & Simulation 2	<b>Session 26</b> [기획] 대량의 공학적 최적설계안 자동 생성을 위한 제너레이티브 디자인 기술 및 생산 연계 기술 개발		
		좌장: 신종호	좌장: 권순조	좌장: 박광필	좌장: 송민석	좌장: 이상부		
	14:30-14:40	휴식						
	14:40-15:40	포스터 발표 (로비, 1F)						
	15:40-17:00	<b>Session 27</b> Machine Learning 2	연구윤리워크숍	<b>Session 28</b> PHM/ Planning & Scheduling/ Robot	<b>Session 29</b> VR/AR/XR/Metaverse	<b>Session 30</b> [기획] 조립 및 물류 시스템의 AI 기반 동적 스케줄링	<b>Session 31</b> [기획] 중견·중소 조선소 작업환경 안전보건을 위한 Smart HSE	
		좌장: 유원선		좌장: 강경수	좌장: 원종윤	좌장: 우종훈	좌장: 김환석	

2.1 (Thu)	10:00-12:00	Panel Discussion						
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Session 18 CAD/CAM/Design Engineering/Nano/MEMS Applications 1		좌장: 이진원
S18-1	케이블 자동 라우팅을 위한 3차원 길찾기 문제에서 심층 강화학습의 적용 *김군찬, 윤영준, #권순조 (국립금오공과대학교)	185
S18-2	멀티모달 오토인코더를 활용한 3D CAD 모델 특징 추출 *윤영준, 김재연, #권순조 (국립금오공과대학교)	186
S18-3	AI 기반 건축 설계 프로세스에 대한 연구 - LLM 및 생성형 AI를 중심으로 - *정희건, #김성아 (성균관대학교)	187
S18-4	점군 데이터를 활용한 선박 소부재 경계 추출 방법 *이노준, 김상우, #권기연 (국립금오공과대학교)	195
S18-5	점군 데이터를 활용한 배관 형상 인식 방법 *김상우, 이노준, #권기연 (국립금오공과대학교)	197

Session 19 Modeling & Simulation 1		좌장: 윤태호
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S19-2	시뮬레이션 기반 유전알고리즘을 이용한 환적 중심 컨테이너 터미널의 야드크레인 배치 계획 최적화 연구 *이태훈, 강봉권, #홍순도 (부산대학교)	204
S19-3	트랜스포터 작업 효율 계산을 위한 이동 비용 비교 방법 *유병우, #박광필 (충남대학교)	207
S19-4	평면도 스케치를 통한 알루미늄 프로파일 구조물의 구조 설계 *신윤석, 이환용, #경민호 (아주대학교)	208

Session 20 [기획] 산업현장 및 공공시설 내 공기질 향상을 위한 자율주행 기반 스마트 공기정화장치 및 안전관제 서비스 플랫폼 개발		좌장: 강용신
S20-1	자율주행 기반 스마트 공기정화장치 및 안전관제 서비스 플랫폼 개발 *#오동훈 (신성이엔지)	212
S20-2	디지털트윈 기반 지능형 안전관제 서비스 플랫폼 설계 *이동건, #강용신 (차세대융합기술연구원)	213
S20-3	신규 AGV 플랫폼 Motion Planning 전략 연구 *#임경일 (차세대융합기술연구원)	214
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# 게임 엔진을 사용한 모듈 건물 생산의 이산 사건 시뮬레이션을 위한 임시 프레임워크

## A tentative framework for discrete event simulation of modular building production using game engines

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### ABSTRACT

Traditional methods for simulating modular building production process lack interactivity and realism, limiting effective decision-making and optimization due to their inability to capture the complexities of modular construction workflows. This study proposes a preliminary framework for integrating DES (discrete event simulation) into modular building production using game engines, with the goal of bridging the gap between traditional simulation methods and the dynamic nature of modular construction projects through the use of interactive and visual capabilities. The key steps are preparing data for modular production process, BIM (Building information modelling) designing workflows, configuring the DES model, implementing integration within unity, and finally analyzing, visualizing, and optimizing the results. The proposed framework has the potential to revolutionize modular building simulation and analysis by providing an interactive platform that allows stakeholders to better understand the complexities of real-world construction scenarios, resulting in more informed decision-making and better project management.

**Key Words:** Modular building production, Discrete event simulation, game engine, framework.

### 1. Introduction and background

Modular construction has gained significant attention in recent years due to its potential for high-quality control, rapid construction, risk minimization, and waste minimization [1]. However, traditional methods for simulating the modular building production process often lack interactivity and realism [2]. This limitation hinders effective decision-making and optimization as these methods fail to capture the complexities of modular construction workflows [2]. The disconnect between traditional simulation methods and the dynamic nature of modular construction projects presents a significant challenge. Current simulation models mainly focus on the assembly of modules on-site and often overlook factors such as weather and traffic conditions[3]. This lack of detail can lead to inaccuracies in the simulation results. To address this issue, this study proposes a preliminary framework for integrating DES into modular building production using game engines. The integration of BIM and DES within a game engine has been shown to provide an interactive and visual platform that can better represent the construction process of a facility [4].

The objective of this research is to bridge the gap between traditional simulation methods and the dynamic nature of modular construction projects. This is achieved by defining objectives, assessing technology capabilities, preparing data for BIM and DES, designing workflows, developing BIM models, configuring the DES model, implementing integration, executing simulations, analyzing and optimizing results, visualizing and communicating outcomes, iterating and refining the process, documenting and training, and finally deploying and monitoring the integrated system.

The scope of this research encompasses the entire lifecycle of a modular construction project, from the initial design phase to the final deployment and monitoring of the integrated system.

The proposed framework is applicable to various types of modular construction projects, providing a comprehensive solution for the industry.

The proposed framework has the potential to revolutionize modular building simulation and analysis. By providing an interactive platform that allows stakeholders to better understand the complexities of real-world construction scenarios, it can lead to more informed decision-making and improved project management. Furthermore, the integration of BIM and DES can enhance the precision and efficiency of prefabrication design, contributing to the advancement of the modular construction industry.

### 2. Literature review

The process of representing the behavior of complex systems through a well-defined sequence of discrete events is known as DES [5]. It has been used extensively in the development of computer simulation models for assessing and improving the dynamics of building projects, such as the CYCLIC Operational Network (CYCLONE) [6]. Similarly, another researcher employs DES using the Symphony.NET tool to model the process of transporting modules and assembling them on a construction site for a future multi-residential project [3]. To address the challenge in balancing efficiency with customization in modular construction, a DES is built to simulate the entire manufacturing process [7]. This approach assesses the efficiency of the production system, identifies potential bottlenecks, and demonstrates an increase in production from 6.8 to 7.7 modules per month solely by improving workforce utilization through various what-if scenarios. A new facility layout is also proposed for maximum flexibility, allowing for the production of high-quality, diverse products that are tailored to customer demands. Another article discusses the underutilization of DES in construction and proposes a framework for integrating DES and

BIM within a game engine to simplify result presentation [4]. This framework enables users to import BIM models, simulate construction activities, and visualize results through animation, making it a useful tool for validation, analysis, and communication with domain experts who are unfamiliar with simulation techniques.

Modular construction is a sustainable and efficient method of building design and fabrication, but it necessitates careful coordination and process optimization. DES is a powerful tool for modeling and analyzing complex systems; however, due to a lack of integration with BIM and user-friendly visualization, it is not widely used in modular construction. As a result, a novel approach that can integrate BIM, Unity, and DES for modular building module manufacturing process to aid decision making is required. This approach would allow the development of realistic and interactive simulation models capable of capturing the dynamics of the manufacturing process, identifying, and eliminating bottlenecks, and evaluating various scenarios and alternatives. The proposed approach would also improve the quality and efficiency of modular construction projects by facilitating communication and collaboration among stakeholders and domain experts.

### 3. Provisional framework

Figure 1 shows the proposed provisional framework for integrating BIM, Unity, and DES to improve the modular building manufacturing process in a factory. The framework is composed of 4 different data models: BIM design, Modular production data, DES model configurations, and Unity Integration Platform. The subsequent sections will describe these models in detail.

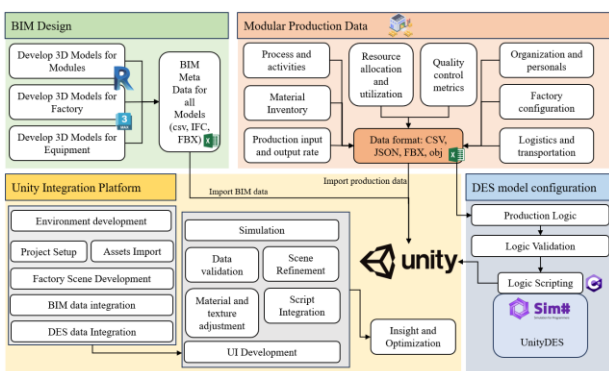


Fig. 1. Proposed provisional framework

#### 3.1. BIM design

The BIM Designing section is dedicated to the meticulous creation of a BIM for modular building production. Beginning with a clear definition of the project scope, this section involves using BIM software Autodesk Revit to design 3D models of individual modules, incorporating detailed information on geometry, materials, and properties. Parameters are carefully set to facilitate the inclusion of vital metadata, ensuring accurate representation. The final step involves exporting BIM data in a compatible format for Unity, often leveraging industry-standard formats such as IFC (Industry Foundation Classes) or FBX, ensuring seamless integration with the subsequent stages of the

framework.

#### 3.2. Modular production data

The focus of this model shifts to the gathering and arrangement of crucial information required for the manufacturing of modular building components. It includes information about the procedures and actions involved in the production of modules. This comprises information on the inventory of materials and components, production input and output rates, resource allocation and utilization, metrics for quality control, organizational and personnel data, factory layout and configuration, logistics, and transportation data.

All of this data will be effortlessly incorporated into Unity and the DES platform in a variety of forms, including CSV, JSON, and 3D files such as FBX or OBJ. In particular, resource allocation plays a critical role in determining machinery, personnel, and production rates. Furthermore, strict quality standards and inspection criteria are set to ensure that the acquired data is not only quantitatively valuable but also aligns with established quality benchmarks.

#### 3.3. DES model development

The DES Model Development comprises the establishment of a comprehensive DES model that thoroughly depicts the modular building production process. A module production logic for the DES will be created using the modular production data. This logic will be validated using standalone software programs such as Anylogic prior to integration into Unity, successfully finding and correcting problems in the production logic. The integration into Unity will be performed through scripting, employing the SIM# library in the C# language or the UnityDES model. The DES model identifies events and defines their triggers, allowing for a full investigation of the temporal elements of production. The time requirements for each stage are thoroughly examined, and dynamic resource allocation techniques are included within the DES model.

The model, which is designed to handle incorrect scenarios and unforeseen events, ensures a realistic and robust simulation of the modular manufacturing process. This method ensures that the complexities involved are accurately represented, providing significant insights into the temporal and resource dynamics of the modular building workflow.

#### 3.4. Unity integration platform

The Unity Integration Platform serves as the nexus where BIM data, modular production data, and the DES model converge for visualization and interaction. BIM data is seamlessly imported into Unity, with careful consideration for scaling and positioning. The DES model is intricately integrated, fostering real-time synchronization with the Unity platform. Data mapping is employed to connect information from diverse sources, ensuring a cohesive virtual representation of the modular building production. User interaction is implemented through developing user interface, allowing users to navigate the virtual environment and actively engage with modular components.

##### 3.4.1. UI and insights



UI, and Insights is the sub-model with unity integration platform which focuses on providing users with a rich and informative experience. A user-friendly interface is designed, incorporating controls for simulation manipulation. Data visualization techniques are employed to present key insights derived from both the BIM data and the ongoing DES simulation. Interactive dashboards allow users to explore data and adjust simulation parameters in real-time. Performance metrics are integrated, offering a comprehensive view of the efficiency and effectiveness of the modular production process. This section ensures that the framework not only operates seamlessly but also provides meaningful insights and a user-centric experience.

This framework provides a structured approach to integrating Unity, BIM, and DES for modular building production. It emphasizes the importance of clear objectives, thorough data preparation, and iterative refinement to achieve an efficient and effective production process.

#### 4. Conclusion

This paper addresses the lack of interactivity of traditional simulation for modular building construction process by proposing a provisional framework for integrating BIM, modular construction, Unity, and DES. The framework provides data requisites and workflow for creating an interactive simulation for modular construction. The proposed framework has the potential to revolutionize modular building simulation and analysis by providing an interactive platform that allows stakeholders to better understand the complexities of real-world construction scenarios, it can lead to more informed decision-making and improved project management. Furthermore, the integration of BIM and DES can enhance the precision and efficiency of prefabrication design, contributing to the advancement of the modular construction industry.

#### Acknowledgements

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