Transforming Construction with Offsite Methods and Technologies - TCOT 2026 Conference

August 18-20, 2026, Newcastle upon Tyne, UK

# A MODULAR MANAGEMENT INFORMATION SYSTEM FOR REAL-TIME RAIL LOGISTICS, OFFSITE SUPPLY CHAIN INTEGRATION, AND JUST-IN-TIME INVENTORY OPTIMISATION

Gouda Mohamed, A.[1],*, Daoud, A.O.[2], Nabil, F.M.[3], and Nabawy, M.[4]

[1*]Associate Professor, Faculty of Engineering, Construction Engineering and Management, The British University in Egypt, Egypt. (corresponding author). E-mail: ahmed.ghanem@bue.edu.eg.

[2]Assistant Professor, Faculty of Engineering, Construction Engineering and Management, The British University in Egypt, Egypt. E-mail: ahmed.daoud@bue.edu.eg.

[3]Graduate Student, Faculty of Engineering, Construction Engineering and Management, The British University in Egypt, Egypt. E-mail: Fares 211744@bue.edu.eg.

[4]Assistant Professor, Faculty of Engineering, Construction Engineering and Management, The British University in Egypt, Egypt. E-mail: mohamed.nabawy@bue.edu.eg.

**Abstract:** The transition toward more industrialised, digitalised, sustainable, and resilient construction systems requires integrated control of procurement, logistics, inventory, and site coordination, particularly where offsite fabrication, supplier-side kitting, and distributed storage must feed time-sensitive rail installation zones. Large-scale rail infrastructure projects are especially affected by geographically dispersed operations, fragmented communication, limited real-time visibility, and inefficient material control, which collectively contribute to delays, waste, and cost overruns. This study develops and prototypes a Rail Logistics Management System (RLMS) as a modular Management Information System designed to coordinate real-time logistics, offsite supply chain interfaces, and Just-In-Time inventory practices in complex rail construction environments. The research follows a design-science, prototype-driven approach comprising problem definition, requirements synthesis from literature and rail logistics workflow mapping, data and process modelling, interface prototyping, and illustrative scenario demonstration. The proposed system integrates procurement management, shipment tracking, distributed storage control, site material requests, and performance reporting within a unified digital platform. Entity-relationship diagrams, sequence models, state transition logic, and role-based access management are used to support data integrity, traceability, and process consistency across modules. By linking operational transactions to real-time dashboards, the RLMS offers a conceptual basis for improved transparency, proactive decision-making, and offsite-on-site coordination. The study contributes a socio-technical digital framework for rail logistics management, while recognising that future case, simulation, or field validation is required to quantify operational benefits.

**Keywords: Rail Logistics; Offsite Construction; Digital Supply Chain Integration; Just-In-Time Inventory; Data-Driven Decision-Making.**

## 1 INTRODUCTION

The construction sector is undergoing a transition toward more industrialised, digitalised, sustainable, and resilient systems of practice, driven by the increasing integration of advanced technologies, real-time data, and offsite construction methods. Within this context, large-scale rail infrastructure projects present a particularly challenging environment due to their linear, geographically dispersed nature, dependence on tightly coordinated material flows, and exposure to delays caused by fragmented procurement, logistics, inventory, and site coordination systems. Traditional management approaches, which rely on disconnected workflows and manual tracking, limit transparency, weaken stakeholder coordination, and reduce the ability to make proactive decisions across both offsite and on-site operations. As a result, rail projects continue to experience inefficiencies in material delivery, inventory control, and operational synchronization, underscoring the need for an integrated digital platform that supports real-time monitoring, offsite supply chain coordination, and Just-In-Time delivery strategies.

The issue at hand is the lack of a single digital platform that can unify the entire rail logistics lifecycle across procurement, inventory, delivery coordination, and the interface between offsite supply chains and on-site operations. Existing disjointed methodologies contribute to delays in procurement, weak coordination among stakeholders, and limited real-time tracking of ordered, stored, and installed materials. These inefficiencies expose a significant gap in practice, particularly at a time when construction research and practice are increasingly focused on integrated digital systems, supply chain management, and coordinated offsite-onsite processes. Consequently, there is a clear need for a platform that automates workflows, provides end-to-end traceability, and supports proactive inventory control in a more industrialized, digitalized, and data-informed project delivery environment.

To bridge the existing gap, this study develops and prototypes a comprehensive Rail Logistics Management System (RLMS). The system is conceptualised as a modular Management Information System that consolidates procurement, logistics, warehousing, and site operations into a single integrated platform, while also supporting coordination between offsite supply chains and on-site delivery activities. By leveraging structured data modelling, automated workflows, and role-based access control, the RLMS enables real-time tracking of materials and supports the implementation of Just-In-Time inventory practices in a more industrialised, data-driven project environment. Consequently, the system contributes to improved decision-making, enhanced transparency, and greater operational efficiency among stakeholders operating in complex rail infrastructure environments, while also responding to the growing need for integrated offsite-onsite processes, supply chain management, and advanced digital coordination in construction.

## 2 LITERATURE REVIEW

Offsite construction changes the logistics problem from simple material delivery to the coordination of production, consolidation, storage, transportation, and site installation across multiple locations and organisations. Recent research on offsite construction supply chains shows that modelling material flows, supplier interfaces, and logistics constraints is essential for achieving the expected benefits of industrialised construction (Hussein et al. 2021). BIM-based offsite management studies similarly emphasise that project requirements, production status, and installation information must be integrated to support reliable delivery across offsite and on-site activities (Jang et al. 2022).

Rail infrastructure projects intensify this challenge because work packages are distributed along extended corridors rather than concentrated on a single site. Logistics decisions therefore need real-time visibility of purchase orders, shipments, storage locations, and site requests. Digital construction logistics research indicates that 4D BIM and information-management tools can improve the understanding of logistics constraints, site access, and construction sequencing (Whitlock et al. 2021). IoT-enabled tracking and cloud-based data exchange can further support supply-chain visibility when materials, equipment, and deliveries move across several parties (Jahan et al. 2022; Yenugula et al. 2023).

Just-In-Time (JIT) logistics is particularly relevant to offsite and modular construction because prefabricated components often require protected handling, limited storage time, and precise delivery to installation zones. A systematic review and meta-analysis of JIT in modular integrated construction identified coordination, supplier reliability, information sharing, and workflow planning as critical factors for successful implementation (Hussein and Zayed 2021). These findings support the need for a system that connects demand signals from rail sites with procurement, supplier confirmation, storage availability, and shipment release.

The RLMS is therefore conceptualised as a unified digital platform that integrates procurement, logistics, inventory management, and site operations into a single system. It embeds JIT inventory principles, standardised procurement procedures, data centralisation, and role-based access control to facilitate coordination, transparency, and operational efficiency. Its development strategy is based on object-oriented system design and Management Information System principles, using a prototype-based methodology that allows system components to be refined iteratively and aligned with rail/offsite logistics requirements.

Existing construction technology platforms often support useful but separate functions, such as document collaboration, procurement administration, model coordination, or project reporting. However, they are less explicit in linking supplier-side production, distributed storage, inventory thresholds, shipment control, and site requests in one state-controlled workflow for rail infrastructure. This limitation is important because offsite delivery depends on synchronising external production and logistics activities with site readiness, rather than simply recording transactions after they occur.

The novelty of the proposed RLMS lies in combining these functions within a rail-specific, modular MIS architecture. Unlike generic digital construction or logistics platforms, the system models the full material lifecycle through linked entities, rule-based state transitions, role-specific permissions, and dashboards that connect procurement, storage, shipment, and site confirmation data. This integration is intended to make the offsite-to-site interface traceable and auditable while supporting JIT material decisions.

Despite the advantages of integrated digital platforms, barriers to adoption remain, including resistance to digital transformation, cybersecurity concerns, implementation cost, and interoperability challenges, especially in developing regions (Onatere-Ubrurhe et al. 2024). These barriers indicate that system architecture must be modular, role-based, and capable of progressive implementation rather than assuming immediate replacement of all existing enterprise systems.

Accordingly, the literature points to two connected gaps: the need to strengthen offsite supply-chain coordination in construction logistics, and the need to translate this coordination into a practical digital architecture for rail projects. This study addresses these gaps by developing a conceptual and prototype-level RLMS that integrates procurement, logistics, storage, and site operations into a modular framework responsive to the geographically dispersed characteristics of rail infrastructure projects.

## 3 METHODOLOGY

This study adopts a design-science, prototype-oriented methodology to develop the Rail Logistics Management System (RLMS), a Management Information System tailored to the logistical and procurement requirements of large-scale rail infrastructure projects. The methodology follows five linked stages: (1) problem definition from rail logistics and offsite coordination challenges; (2) functional requirements synthesis from the literature and workflow mapping; (3) data and process modelling using ERD, sequence, and state diagrams; (4) prototype interface and dashboard development; and (5) illustrative scenario demonstration. This approach is appropriate for conceptual system development, while measured performance validation is identified as a future research stage.

The requirements stage focused on the characteristics of rail construction projects, including extended linear configurations, geographically dispersed operational zones, and the need to coordinate offsite suppliers, storage yards, and on-site installation teams. These characteristics, combined with fragmented communication processes, reliance on manual tracking, and limited integration between procurement and logistics functions, introduce operational inefficiencies that affect project performance. The RLMS was therefore framed around material traceability, JIT decision support, role-based governance, and integration between offsite supply-chain nodes and site demand.

The system's scope encompasses key operational domains, including procurement lifecycle management, real-time logistics tracking, inventory control across distributed storage facilities, material request and delivery coordination for remote sites, and performance monitoring through reporting and key performance indicators. To support these functions, the RLMS is designed as a modular system comprising five integrated subsystems: procurement management, logistics and shipment tracking, storage and inventory control, site request management, and MIS-based reporting. These subsystems are interconnected through defined data flows and governed by structured user roles to ensure consistency, scalability, and secure system interaction. The architecture follows a layered design comprising a data layer defined through Entity–Relationship modelling, a logic layer that incorporates workflow rules and process automation, and a user interface layer that facilitates role-based interaction with the system.

According to the architecture in Figure 1, the development process follows a prototype-driven framework that progresses through sequential yet interrelated stages. It begins with database design and Entity–Relationship Diagram (ERD) modelling to establish a consistent, scalable data structure that represents key system entities, including users, companies, purchase orders, shipments, packages, storage areas, and item requests. This is followed by implementing the business logic layer, where workflow automation is defined using sequence modelling to represent interactions among users, system components, and external entities, such as suppliers. State-based process modelling is then employed to control the lifecycle of procurement and logistics operations, ensuring that each system object transitions through predefined states in accordance with event-driven rules. Subsequently, the user interface layer is developed, incorporating role-based dashboards and interactive interfaces that allow stakeholders to perform their tasks efficiently. The final stage involves system monitoring and reporting mechanisms that enable real-time tracking, data visualisation, and performance evaluation.

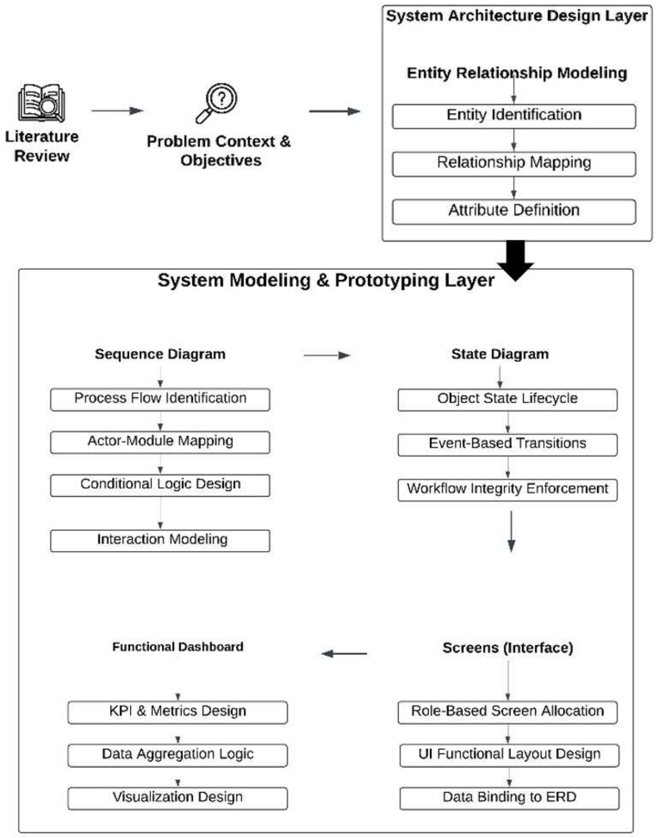


Figure 1. Framework methodology showing the sequence from problem definition to database modelling, workflow modelling, interface prototyping, and dashboard reporting

The operational logic of the RLMS is governed by a state transition model that ensures consistency and traceability throughout the material lifecycle. Each process follows a structured sequence: inventory verification, automatic purchase order generation when stock levels fall below predefined thresholds, supplier confirmation, storage of received materials, shipment dispatch, and final delivery to the site. This state-based control prevents invalid operations, such as dispatching materials before verification or bypassing procurement procedures, thereby enhancing system reliability and accuracy. In parallel, the system implements role-based access control to regulate user interaction and system permissions, assigning specific access rights to procurement officers, logistics managers, site engineers, storage personnel, and administrators. This approach ensures that users interact only with relevant system functions, reducing errors, enhancing accountability, and maintaining data security.

As presented in Table 1, the state diagram governs material and procurement transactions in the RLMS, with each object progressing through defined states via rule-based transitions. It maps how events change system states and ensures consistent behaviour across inventory, procurement, storage, shipment, and delivery modules (Jahan et al. 2022). This prevents errors such as shipping unverified packages or bypassing receipt confirmation, thereby improving traceability across the rail logistics process.

Table 1: State transition flow of the rail logistics management process

| State | Event / Action | Next State |
|---|---|---|
| Inventory Checked | Stock Threshold | Purchase Order Created |
| Purchase Order Created | Confirm Receipt from the supplier | Purchase Order Items Confirmed |
| Purchase Order Items Confirmed | Store items arrive at storage | Package Stored |
| Package Stored | Send logistics dispatch initiated | Shipment Sent |
| Shipment Sent | Deliver to the site | Delivered & Closed (optional state) |

Finally, the RLMS integrates a centralised Management Information System that aggregates data from all modules into real-time, role-specific dashboards. These dashboards provide continuous visibility into procurement status, shipment progress, inventory levels, and site demand, enabling stakeholders to make informed decisions based on accurate and up-to-date information. By directly linking system transactions to reporting interfaces, the RLMS ensures data consistency, traceability, and transparency, supporting forecasting, auditing, and performance monitoring across the entire project lifecycle. Table 2 shows that RLMS uses role-based access to grant necessary permissions, reducing errors. Interfaces display role-specific functions, ensuring secure workflows.

Table 2: Roles and access rights

| Role | Access Rights |
|---|---|
| Procurement Officer | Create/approve POs, assign suppliers, monitor PO status |
| Logistics Manager | Trigger package dispatch, update shipment status |
| Site Engineer | Submit item requests, confirm deliveries. |
| Storage Officer | Confirm storage receipt, update inventory levels, |
| Project Manager / Admin | Full read/write access, audit logs, export data, and view all dashboards |

Illustrative application scenario. In a representative rail corridor, a site engineer submits a request for prefabricated track-support components required within a three-day installation window. The RLMS checks available stock in the nearest storage yard; if stock is below the threshold, the system generates a purchase order, records supplier confirmation, assigns the package to a storage area, and releases shipment only after receipt verification. The logistics manager then monitors dispatch status, while the site engineer confirms delivery and closes the request. This scenario demonstrates how the prototype coordinates the offsite supplier/storage node with the on-site workface; however, it is not presented as evidence of measured performance improvement.

## 4 CONSTRUCTION SCHEMA

The Rail Logistics Management System (RLMS) is based on a structured relational database that manages procurement, logistics, storage, site requests, and reporting. Defining entities, relationships, and attributes ensures data integrity, scalability, and logical consistency, while also reflecting the operational requirements of offsite-to-site rail logistics. The main business entities mirror rail construction supply-chain actors and transactions, including users, companies, suppliers, storage facilities, packages, purchase orders, shipments, item requests, and reports.

For clarity, Figure 2 should be read as a high-level conceptual map of the main RLMS entities and material-flow relationships. The model connects companies with users who submit item requests and create reports. Purchase orders include line items that identify packages to be delivered; once received, packages are assigned to storage areas and then linked to shipment and site-delivery records. This structure reflects procurement, storage, and distribution processes in a traceable offsite-to-site workflow.

Figure 3 expands this conceptual model by showing entity definitions, attributes, and relationships used to support database implementation. Primary and foreign keys are assigned to key entities such as Users, Purchase Orders, Packages, Storage Areas, and Shipments, while operational attributes such as quantity, status, and timestamps support querying, audit trails, dashboards, and reporting. This figure is detailed because it represents the backend schema rather than a simplified process chart.

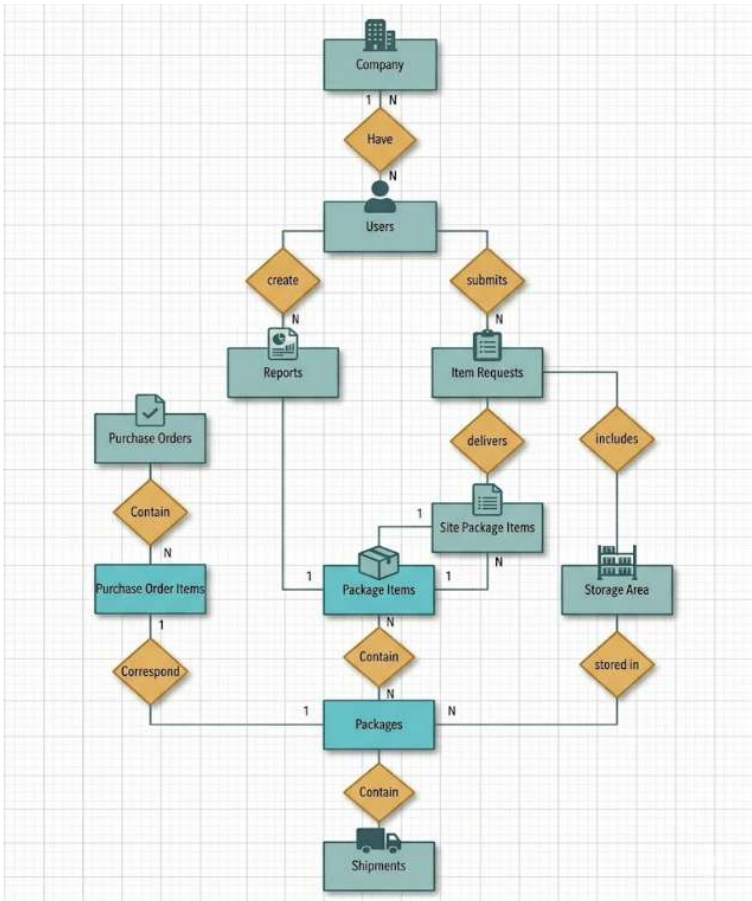


Figure 2. Conceptual entity-relationship model representing the main RLMS entities and material-flow relationships

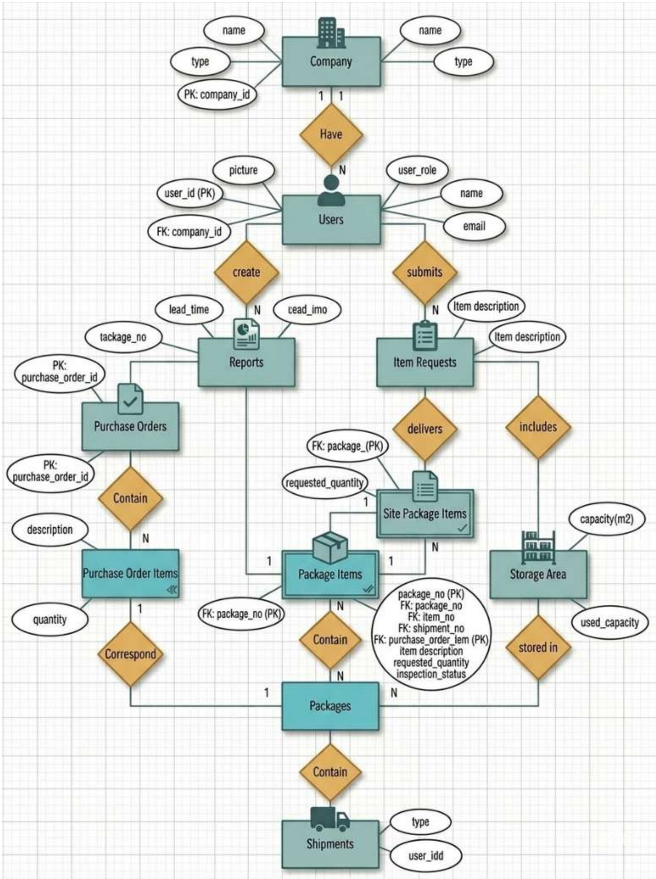


Figure 3. RLMS database schema showing entities, attributes, primary/foreign keys, and relationships used for data integrity

Figure 4 summarises the main interaction sequence among the user, procurement module, inventory/storage module, supplier, logistics module, and site area. The diagram shows how procurement can be triggered by an inventory check when stock is low, followed by supplier confirmation, storage update, shipment monitoring, and site delivery confirmation. This process view complements the database schema by explaining the order of operational events.

Figure 5 presents the RLMS login page and dashboard interface. The dashboard provides a centralised platform for monitoring procurement, logistics, shipment status, inventory levels, and material orders. Role-based access gives project managers high-level indicators while enabling procurement officers, logistics managers, storage officers, and site engineers to view task-specific information. The dashboard is linked to backend data to support early identification of delays and proactive decisions across the rail logistics lifecycle.

Figure 6 presents the users management interface, which supports governance of the system through role assignment and company affiliation. The interface enables authorised users to manage administrative records, assign responsibilities, and control access to procurement, shipment, storage, and reporting functions. This access-control layer reduces unauthorised interaction with sensitive data and helps isolate workflows according to user responsibilities.

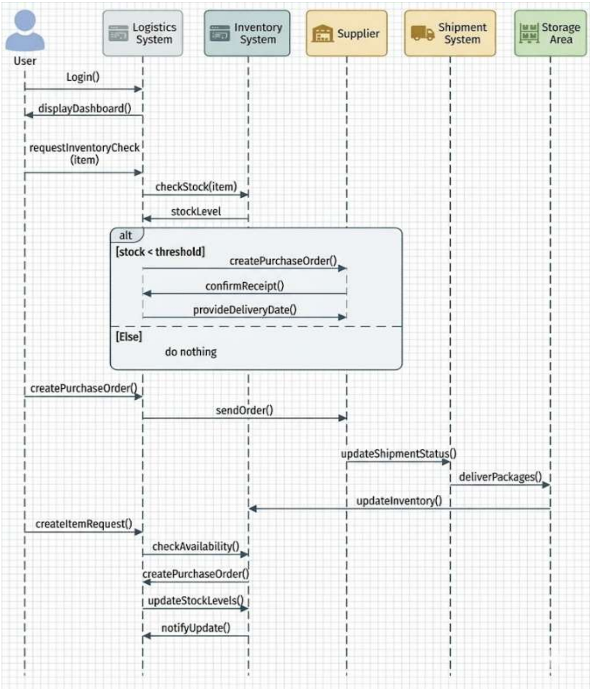


Figure 4. RLMS sequence diagram showing inventory-triggered procurement, supplier confirmation, shipment release, and site delivery confirmation

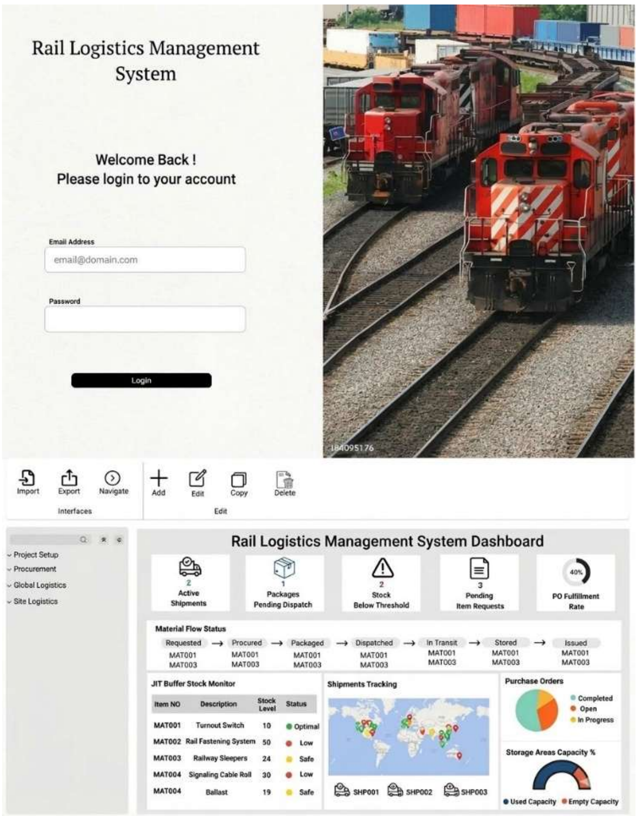


Figure 5. RLMS user interface: login page and role-specific dashboard for procurement, logistics, shipment, inventory, and reporting

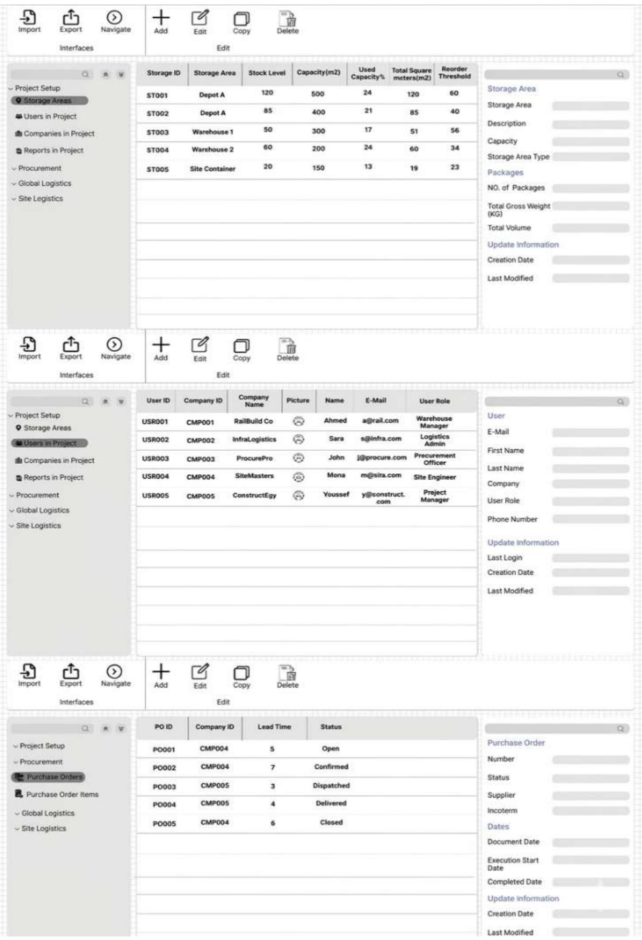

Figure 6. Users management interface showing role assignments, company affiliation, and access-governance functions

## 5 CONCLUSION

The paper outlines the conceptual design, modelling, and prototyping of the Rail Logistics Management System (RLMS), developed to address procurement, logistics, storage, site-request, and reporting challenges in large-scale rail infrastructure projects. By explicitly linking offsite supply-chain nodes with on-site rail construction demand, the RLMS frames logistics as an enabling mechanism for offsite construction rather than a separate administrative function. The study resulted in a modular MIS architecture that combines data modelling, workflow automation, role-based access control, and interactive interfaces.

The RLMS prototype illustrates how a state-controlled digital logistics system could improve coordination between procurement, suppliers, storage teams, logistics managers, and site engineers. Its role-based architecture supports secure stakeholder interaction, while real-time dashboards provide visibility into procurement status, inventory levels, shipments, and deliveries. However, these benefits remain conceptual at this stage because the system has not yet been tested using live project data, simulation experiments, or real operational deployment.

Future work should validate the RLMS through a real rail project case study, controlled simulation, or historical data set to quantify effects on delivery reliability, stockout frequency, procurement lead time, and site waiting time. Further development should also consider cloud implementation, interoperability with ERP and supplier systems, predictive procurement optimisation using AI, and mobile interfaces for field teams.

The current study therefore provides a methodological and architectural basis for future validation and industry implementation of integrated offsite-on-site rail logistics management.

## 6 REFERENCES


Hussein, M., Eltoukhy, A. E. E., Karam, A., Shaban, I. A., & Zayed, T. (2021). Modelling in off-site construction supply chain management: A review and future directions for sustainable modular integrated construction. Journal of Cleaner Production, 310, 127503. https://doi.org/10.1016/j.jclepro.2021.127503

Hussein, M., & Zayed, T. (2021). Critical factors for successful implementation of Just-in-Time concept in modular integrated construction: A systematic review and meta-analysis. Journal of Cleaner Production, 284, 124716. https://doi.org/10.1016/j.jclepro.2020.124716

Jahan, S., Rahman, M., & Khan, A. (2022). Real-time IoT-based inventory management in logistics. PMC National Center for Biotechnology Information. Retrieved from https://pmc.ncbi.nlm.nih.gov/articles/PMC8005061

Jang, Y. E., Son, J., & Yi, J. S. (2022). BIM-based management system for off-site construction projects. Applied Sciences, 12(19), 9878. https://doi.org/10.3390/app12199878

Onatere-Ubrurhe, J. O., Ubrurhe, O., & Ugworji, C. T. (2024). Leveraging cloud computing for collaborative project management in the Nigerian construction sector: Benefits, challenges, and prospects. European Journal of Computer Science and Information Technology, 12(8), 69-91.

Whitlock, K., Abanda, F. H., Manjia, M. B., Pettang, C., & Nkeng, G. E. (2021). 4D BIM for construction logistics management. CivilEng, 2(2), 325-348. https://doi.org/10.3390/civileng2020018

Yenugula, M., Sahoo, S. K., & Goswami, S. S. (2023). Cloud computing in supply chain management: Exploring the relationship. Management Science Letters, 13, 193-210. https://doi.org/10.5267/j.msl.2023.4.003