International Journal of Core Engineering & Management
Volume-7, Issue-02, 2022 ISSN No: 2348-9510

IMPLEMENTATION OF BIM IN OPTIMIZATION OF ITERATIVE ROUTINE OPERATIONS FOR CONCRETE MANUFACTURING UNIT

Aayush Goel
Austin, Texas
aayushgoel111@gmail.com

Abstract

The demand for ready-mix and prefabricated concrete has significantly risen over the decades within the construction industry, driving fluctuating demands that exacerbate daily challenges for ready-mix concrete (RMC) suppliers. Key issues include optimizing inventory management, scheduling, and monitoring of concrete-delivery truck mixers, as well as ensuring effective coordination between suppliers and contractors. Despite extensive research addressing these challenges, the dynamic nature of the operation phase in the RMC supply chain demands continuous innovation and enhancement. This study explores the application of Building Information Modeling (BIM) as a transformative solution by enabling the integration, visualization, and efficient reuse of real-time data to enhance coherence and productivity across operations. Using case studies and literature reviews, this research analyzes the persistent challenges faced by RMC suppliers and proposes BIM-supported solutions for improving operational efficiency and sustainability.

Keywords: Building Information Modelling (BIM), Ready-Mix Concrete (RMC), Inventory Management, Real-Time Data Integration, Sustainable Construction, 3D Modelling, Automated Dashboard

I. INTRODUCTION

Concrete remains one of the most fundamental materials in the construction industry, serving as a cornerstone in the completion of projects of varying scales. Traditionally, contractors relied on on-site mixing using concrete transit mixers to meet project requirements. However, as the construction industry evolved, spurred by technological advancements and the advent of complex infrastructures, there arose a significant demand for specialized ready-mix concrete (RMC). This surge necessitated the establishment of numerous RMC manufacturing facilities to accommodate market expectations for high-quality and customized concrete mixes (Park et al., 2011).

The rising demand for ready-mix concrete has presented challenges in supply chain logistics, including efficient inventory management, on-time delivery, and seamless in-plant operations. RMC production involves intricate iterative processes that must account for the coordination among multiple stakeholders, such as suppliers, contractors, and transporters. Delayed deliveries often disrupt construction schedules, triggering cascading delays across subsequent activities and, ultimately, prolonging project timelines. Moreover, ensuring post-placement concrete quality on-site remains a critical issue, as there are limited precise methods to verify its compliance with quality standards.

Concrete's perishable nature further complicates production and transportation logistics. Concrete begins to harden within a narrow window of 0.5 to 1.5 hours post-production, necessitating immediate dispatch to construction sites (Crawford et al., 2015a; Research Services Section, 2011). Effective dispatch planning, therefore, becomes paramount but is often hindered by fluctuating demand, inventory uncertainties, and traffic constraints (Zhang, 2011; Zhang et al., 2011). Additionally, to ensure uninterrupted production, suppliers must proactively monitor raw material inventories, addressing potential shortages to meet dynamic market demands.

Environmental concerns compound the challenges of RMC production. Studies have shown that nearly 24% of India's CO2 emissions originate from construction activities (Parikh et al., 2009). Transportation of RMC contributes significantly to energy consumption and emissions, exacerbating the sector's environmental footprint. Globally, the transportation sector accounts for approximately 23% of greenhouse gas emissions—a statistic reflective of the environmental toll associated with RMC logistics (Crawford et al., 2015). Addressing these challenges necessitates innovative solutions to mitigate emissions and streamline operations.

TABLE I. Issues addressed from literature review

Issues addressed	References
Efficient dispatch of resources (e.g., pipes, pumps) to optimize manpower usage and reduce idle time.	(Zhang 2011; Zhang et al. 2011)
Routing of vehicle and delivering concrete on time in metropolitan areas while minimizing costs	(Galić and Kraus 2016)
Achieving an economical supply of RMC by optimizing transit mixer dispatch intervals and minimizing queuing.	(Lu and Lam 2009; Park et al. 2011; Talian 2013; Zayed and Minkarah n.d.; Zhang et al. 2011)
Quantifying emissions and evaluating their environmental impacts.	(Cazacliu and Ventura 2010; Sandanayake et al. 2019)
Reducing production costs and maximizing RMC output to minimize material wastage.	(Dunlop and Smith 2002; Smith 1999)
Managing fluctuating concrete demands and optimizing order placement.	(Anson and Siu 2020)

Extensive research has been conducted to address the challenges faced by Ready-Mix Concrete (RMC) manufacturing units during daily operations. This study aims to delve deeper into these challenges, examining how Building Information Modelling (BIM) can be utilized at various stages of iterative processes within RMC units. The objective is to explore innovative applications of BIM that remain relatively untapped, while addressing the obstacles suppliers may encounter during BIM implementation, supported by a detailed case study. Additionally, this study assesses the environmental impacts associated with concrete manufacturing and proposes BIM-supported methods to monitor and mitigate these effects.

The subsequent sections of this paper are structured as follows:

- The next section reviews the current practices in RMC operations and identifies major challenges faced by suppliers.
- Following that, a case study is presented, analysing daily manufacturing operations and highlighting real-world challenges encountered by the supplier.
- The study then discusses insights derived from literature reviews and state-of-the-art advancements, offering potential solutions to these issues.
- Furthermore, it explores implementation challenges associated with BIM and evaluates its feasibility in the context of RMC manufacturing.
- Finally, the paper concludes with actionable recommendations and outlines areas for future research.

II. STATE OF PRACTICE

The production process at a ready-mix concrete (RMC) manufacturing unit involves numerous interconnected operations requiring seamless coordination among various stakeholders, including owners, managers, schedulers, estimators, quality managers, labourers, drivers, and contractors. Effective communication is vital to ensuring smooth operations across the supply chain. However, given the involvement of diverse entities, operational inefficiencies frequently arise, hindering productivity.

Each operation consumes critical resources such as labour, machinery, vehicles, fuel, water, and electricity, emphasizing the need for their efficient utilization. This study identifies and analyses key operations prone to errors, including inventory tracking, transit mixer logistics, demand management, and resource allocation. These operational challenges often disrupt workflows, highlighting the need for innovative solutions to streamline processes and mitigate inefficiencies.

2.1. Tracking of inventory

The initial and most critical operation within a ready-mix concrete (RMC) manufacturing unit is the estimation of existing inventory. This task is typically performed manually by the inventory manager, who physically inspects storage yards and provides approximate estimates of material quantities. While widely practiced, this manual approach is inherently time-consuming and prone to significant errors. Cement and fly ash are stored in silos, whereas fine and coarse aggregates are kept in open storage yards (Crawford et al., 2015).
A semi-automated method has been adopted in some cases, incorporating weighing scales beneath storage yards to determine aggregate weights. However, the high costs associated with the initial setup, operation, and maintenance of this equipment render it impractical for widespread implementation. Consequently, there remains no universally accepted, cost-effective method for accurately tracking inventory.
This situation underscores the need for a comprehensive framework that can mitigate errors in inventory estimation while maintaining economic feasibility. Developing such a system is imperative to optimize resource utilization and streamline daily operations. Figure 1 illustrates the

traditional methodology used for planning daily operations at an RMC manufacturing unit.

2.2. Tracking of transit mixer trucks

The distance between the concrete batching plant and the construction site plays a pivotal role in planning production processes effectively (Park et al., 2011). Concrete is a perishable material that hardens within a few hours, necessitating timely transportation to construction sites to maintain its usability (Research Services Section, 2011). Accurate tracking of delivery vehicles is essential to ensure concrete arrives on-site in optimal condition for pouring.

Traditionally, managers rely on manual communication, frequently calling drivers for real-time updates. However, this method is inherently unreliable, as drivers may provide inaccurate information, and travel times are often subject to variability, causing delays in subsequent production processes. Once the transit mixer reaches the site, managers cannot verify critical details such as the precise unloading time or the duration taken by the contractor to unload the concrete. This lack of transparency prevents accurate quantification of delays or identification of the responsible party, further complicating operations.

To overcome these challenges, implementing advanced tracking systems that provide real-time data on vehicle locations and status is crucial. Such systems can enhance transportation efficiency, reduce operational delays, and support better coordination between suppliers and contractors, ensuring smoother workflows and minimizing disruptions.

2.3. Managing the fluctuating demand

Concrete orders for RMC are typically placed a day in advance by contractors based on projected site requirements (Anson and Siu, 2020). Following this, suppliers allocate a set number of truck mixers to the respective site. However, efficiently managing and scheduling truck mixers remains a significant logistical challenge for suppliers. The improper allocation of mixers can result in operational inefficiencies: an oversupply leads to idle queuing at the site, whereas an undersupply causes delays, leaving the concrete placing crew waiting for subsequent deliveries (Anson and Siu, 2020).

Contractors often place initial orders based on static site schedules, which are subject to frequent updates as construction progresses. Such updates, driven by current work statuses, commonly result in fluctuating concrete demands—either an increase or decrease in the ordered quantities. These demand fluctuations require suppliers to modify schedules and respond rapidly to accommodate changing requirements. Additionally, suppliers must optimize batching operations to meet client demands, minimize idle times, and ensure seamless coordination across operations.

The dynamic and complex nature of the industry, coupled with inconsistent communication, often disrupts the balance between supply and demand. Achieving effective coordination between contractors and suppliers remains a pressing challenge, as mismatches frequently cause delays and inefficiencies in the construction workflow (Chen et al., 2021).

2.4. Energy usage and environmental emissions

Ready-mix concrete (RMC) batching plants are fully automated but require plant operators to perform certain essential operations. Depending on their configuration, the plants are powered by diesel, electricity, or a combination of both (Crawford et al., 2015). Diesel-powered plants utilize generators that, while effective in energy provision, significantly contribute to greenhouse gas emissions, including CO2, CH4, and N2O (Olanrewaju et al., 2020). These emissions result in poor air quality near the manufacturing site, making the environment unsuitable for safe breathing conditions.

In contrast, electricity-driven plants rely on commercially produced power, emitting fewer harmful gases at the site itself. However, the electricity consumed is typically generated by thermal power plants, which release considerable amounts of hazardous gases during production. This creates a challenge in assessing the environmental impact and determining which energy source is preferable for reducing emissions.

Additionally, the exponential rise in concrete demand imposes increased production requirements, amplifying environmental effects. This underscores the need for sustainable measures to monitor and control emissions. Advanced frameworks integrating technologies such as Building Information Modelling (BIM) can help assess and mitigate the environmental impacts of both diesel- and electricity-powered plants. These solutions are vital for achieving a balance between operational efficiency and environmental responsibility (Crawford et al., 2015; Park et al., 2011).

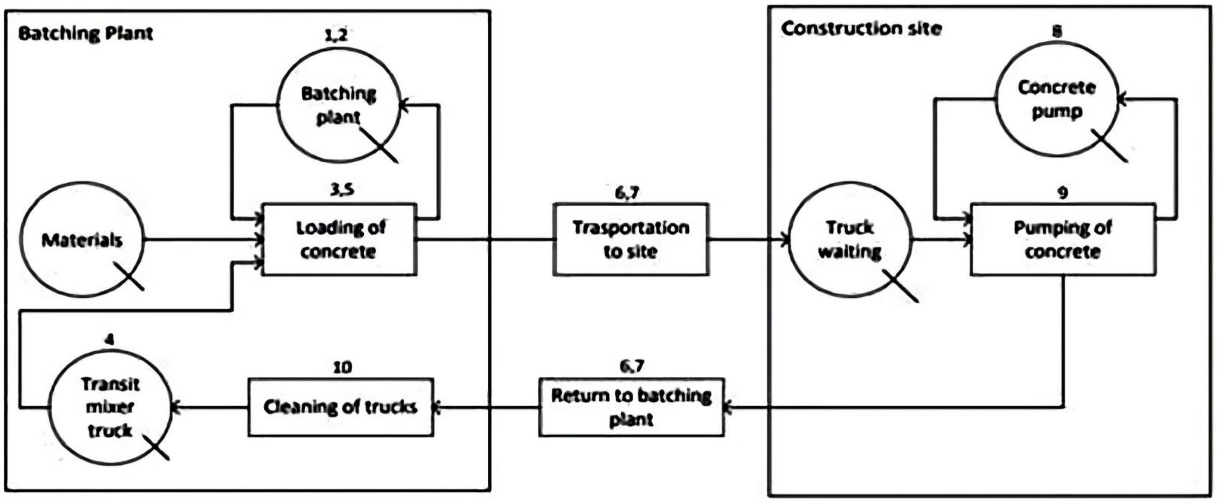

Fig. 1. Traditional method for planning of daily operations (Nellickal et al., 2015)

III. CASE STUDY

3.1. Context

This case study examines the operational methodology and real-world challenges faced by the owner of a ready-mix concrete (RMC) manufacturing unit situated in the industrial hub of Delhi, India, as depicted in Figure 2. Through detailed analysis, the study aims to identify the potential scope for implementing Building Information Modelling (BIM) across various stages of concrete manufacturing and supply processes. By addressing key issues encountered during daily operations, this case study provides insights into how BIM can be leveraged to improve efficiency, collaboration, and sustainability in RMC production and distribution workflows.

3.2. Data Collection

The manufacturing unit analysed in this case study comprises two batching plants—one powered by diesel and the other operating on electricity. The unit includes a fleet of 26 truck mixers, along with additional essential machinery and commercial vehicles to support its operations. To investigate operational challenges, several call interviews and Zoom meetings were conducted with key personnel, including the owner, engineers, schedulers, inventory managers, and labourers. These engagements facilitated a detailed understanding of the daily operations, enabling the identification of critical issues.

The plant employs a workforce of 50 individuals, necessitating robust collaboration and strategic planning to ensure the efficient functioning of the supply chain. Effective communication and task allocation among employees are vital to maintaining smooth workflows and minimizing disruptions.

3.3. Issues Discussed

During the meetings, several critical challenges were identified, which are summarized below:

1. ***Collaboration and Coordination Issues:***
   The supplier struggled with establishing a unified platform for collaboration and task assignment among stakeholders. The absence of such a system led to confusion, delays, and difficulties in attributing responsibility for setbacks in daily operations. These inefficiencies underscored the need for a centralized tool to streamline communication and improve workflow management.

2. ***Inventory Tracking Challenges:***
   Inventory management relied on manual inspections and rough estimations conducted by the estimator and inventory manager. This method proved to be inaccurate, resulting in uncertainty when placing orders for raw materials. Consequently, disruptions in cash flow arose due to payments for improperly forecasted orders, further affecting operational stability.

3. ***Transit Mixer Tracking and Scheduling:***
   Real-time tracking of truck mixers was a significant issue. The scheduler faced challenges in predicting the return time of mixers to the batching unit and preparing them for subsequent deliveries. As a result, adherence to planned schedules was compromised, and concurrent delays became frequent. These delays negatively impacted supplier-contractor relationships and hindered the ability to efficiently address fluctuating demands.

4. ***Energy Consumption and Emissions Analysis:***
   Decision-making regarding which batching plant to operate—diesel-powered or electricity-powered—was impaired due to a lack of accurate data on energy consumption and operational costs. This led to ineffective judgments regarding greenhouse gas emissions and sustainability impacts. The need for a systematic approach to measuring and analysing these factors became evident.

IV. STATE OF ART

Despite numerous efforts to address the challenges faced by ready-mix concrete (RMC) manufacturing units, many of these issues persist, leading to delays and inefficiencies within the construction industry. The inherent limitations of traditional methods, compounded by human error, often prevent optimal planning and scheduling. As no single software or method can perfectly accommodate all constraints, there remains considerable scope for improvement.

This study highlights how Building Information Modelling (BIM) can be integrated with other technologies to develop innovative solutions that address these persistent challenges. Table 2 provides a detailed overview of state-of-the-art methodologies, demonstrating how BIM can be combined with advanced algorithms, automation, and sensor technologies to resolve critical issues and minimize their negative impacts.

TABLE II. Potential solutions for issues addressed

S.no	Issues	Potential Method	References
1.	Accurate estimation of quantities	BIM with algorithms Develop a knowledge-based framework using standardized measurement methods. Quantities can be calculated based on the geometry and 3D semantics of stored raw materials at the unit. BIM with Automation Use robots equipped with sensors to estimate quantities in real-time and share data on a centralized BIM platform.	(Liu et al. 2022) (Reichenbach and Kromoser 2021)
2.	Real-time tracking & scheduling operations of transit mixers to accommodate fluctuating demand	A BIM integrated framework Consider parameters like truck mixer idle time, unloading time, round-trip time, and production rate to optimize schedules. GPS-linked location sensors can feed real-time data to the BIM platform. BIM-based ANN model Use Artificial Neural Networks to forecast delivery sequences for improved efficiency and reduced costs.	(Anson and Siu 2020; Chen et al. 2021; Lin et al. 2010) (Abinesh 2019)

3.	Collaboration and Coordinating Challenges	BIM-based collaboration platform Develop a platform using three-tier architecture and web technologies to manage roles and responsibilities effectively. BIM Based Dashboard Design a dashboard integrating various inputs into a BIM database to enhance collaboration and minimize ambiguity in task assignments.	(Zhang et al. 2017) (Lai et al. 2019)
4.	Measuring energy consumption and environmental impacts	Emission Evaluation Tool Link a construction emissions evaluation tool with BIM to measure and compare greenhouse gas emissions from diesel and electricity powered plants.	(Sandanayake et al. 2019)

The presented literature review above shows the potential solutions that could be developed with the integration of BIM with other available technologies and algorithms.

V. RECOMMENDATION AND APPLICATION OF BIM

Following a thorough analysis of the state of practice, the case study, and the state-of-the-art methodologies, several actionable recommendations were provided to the owner to address the identified challenges effectively.

The primary recommendation involved the implementation of Building Information Modelling (BIM) at critical stages of the manufacturing process. To enhance coordination and collaboration across various entities and employees, it was suggested to adopt cloud-based BIM software. This technology allows for the assignment of roles and responsibilities with clear deadlines, thereby reducing ambiguity, minimizing reliance on paperwork, and avoiding the need for frequent physical meetings. By incorporating such solutions, the manufacturing unit can shift towards a more technology-driven and advanced approach.

For inventory estimation, the use of BIM to create 3D models embedded with geometric data of stored raw materials was recommended. These models enable precise quantity assessments, ensuring more accurate planning for future orders and demand fluctuations.

In the realm of vehicle tracking, integrating GPS-enabled location sensors with a BIM platform could offer real-time data collection. This data can be used to perform simulations, facilitating efficient scheduling and forecasting for seamless operations and reducing delays.

Furthermore, for assessing energy consumption, it was proposed to implement BIM-based energy analysis tools. These tools can calculate total energy usage and distribute the data across various stages of the manufacturing process. This approach ensures an in-depth evaluation and fosters sustainable decision-making practices.

VI. CHALLENGES IN IMPLEMENTING BIM FOR RMC

Implementing Building Information Modelling (BIM) at a ready-mix concrete (RMC) manufacturing unit presents several potential challenges, particularly in the context of India. One significant barrier is the lack of adequate resources and advanced technologies necessary to establish a dedicated BIM department. The workforce, spread across different departments, has limited exposure to BIM, making the adoption process time-intensive and requiring substantial training to incorporate it into daily operations effectively.

Another considerable challenge is the substantial investment needed to set up sensors and BIM-based software. High initial costs, combined with ongoing maintenance expenses, can pose financial constraints for the owner, especially when resources are already stretched thin. Additionally, since BIM is still in its introductory stage in India, the industry lacks widespread awareness of the latest technologies and global trends, further hindering its adoption.

To address these obstacles, further research and case studies are essential. These efforts could provide insights into cost-effective and efficient BIM implementation strategies, making the transition smoother and more economical. Promoting industry awareness and capacity-building programs will also play a pivotal role in facilitating BIM adoption and bridging the technological gaps.

VII. VISION OF REAL-TIME AUTOMATED DASHBOARD

A fully integrated BIM dashboard or framework, as illustrated in Figure 2, could be developed to collect real-time data and efficiently reuse it to plan daily operations. The data would be gathered using advanced technologies, such as laser scanning, 3D modelling, RFID tags, GPS sensors, and other practices highlighted in the state-of-the-art methodologies.

This BIM-integrated framework would start with automated quantity estimation of existing inventory. By comparing the inventory data with fluctuating demand, the system could assist in planning future orders for raw materials, ensuring accuracy and minimizing waste.

Subsequently, the framework could optimize truck mixer scheduling through live tracking, estimating the time required for mixers to complete specific deliveries. Parameters such as the distance from the manufacturing unit to the construction site, traffic conditions, type of pouring, and the availability of drivers and labour would be considered. Simulations could then be conducted to identify the best possible timings, synchronizing the truck mixer's schedule with the client's requirements and managing fluctuating demands effectively.

The methodologies discussed in state-of-the-art research can be adapted and enhanced to develop this dashboard, offering a comprehensive solution to streamline operations and improve decision-making processes across the supply chain.

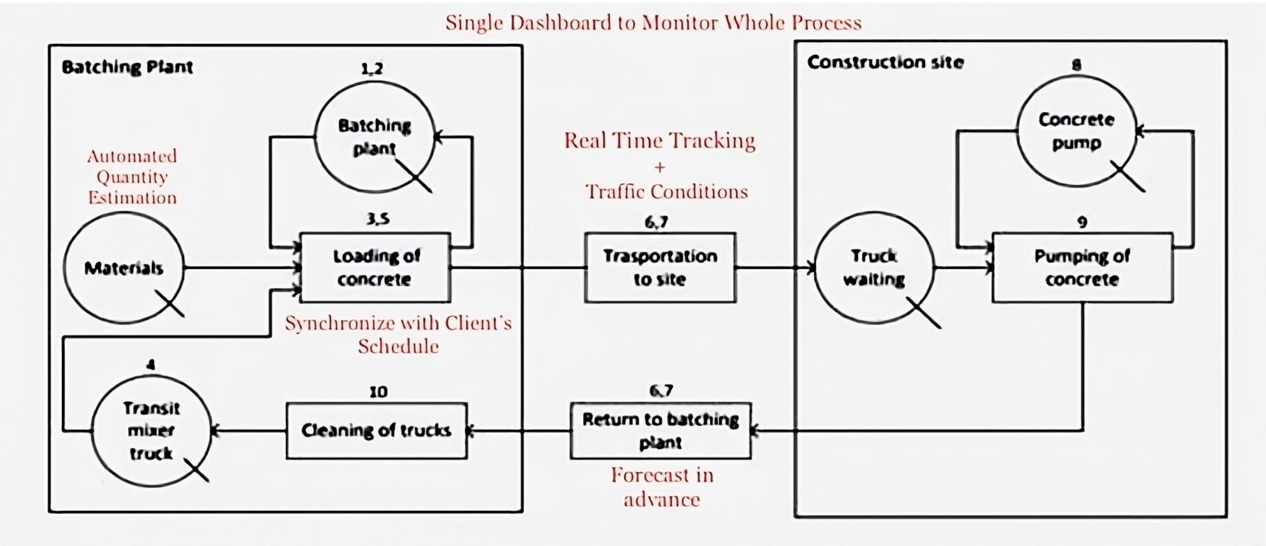

Fig. 2. Scope of implementation of BIM (Nellickal et al., 2015)

VIII. CONCLUSION

Based on the comprehensive analysis conducted through literature review and case study, this paper identifies and elaborates on the critical challenges faced by suppliers in the ready-mix concrete (RMC) industry during daily operations. In response to these challenges, potential solutions leveraging Building Information Modelling (BIM) and other technologies have been proposed. While these generalized solutions provide a useful starting point, further research supported by detailed case studies is essential for a deeper exploration of these issues. Such research could consider a broader range of influencing factors, including geographical location, market dynamics, wastage evaluation, production efficiency, and economic constraints.

The findings presented in this study offer a valuable foundation for researchers striving to enhance the efficiency of daily RMC operations. Moreover, this paper highlights BIM's substantial potential in addressing real-world challenges, forecasting future operations, and enabling proactive problem analysis. By adopting BIM and integrating advanced technologies, the construction industry can move toward greater efficiency and reliability, ensuring sustainable growth and improved workflows.

REFERENCES

1. K. Abinesh, "Forecast of Ready-Mix Concrete Operation by Neural Network," 2019.
2. M. Anson and M.-F. F. Siu, "Augmented Balance Point Diagrams for Matching Site and Concrete-Supply Resources," J. Constr. Eng. Manage., ASCE, vol. 146, no. 4, p. 04020021, 2020.
3. Cazacliu and A. Ventura, "Technical and environmental effects of concrete production: Dry batch versus central mixed plant," J. Clean. Prod., vol. 18, no. 13, pp. 1320–1327, 2010.
4. Q. Chen, B. García de Soto, and B. T. Adey, "Supplier-contractor coordination approach to managing demand fluctuations of ready-mix concrete," Autom. Constr., Elsevier B.V., vol.

121, 2021.

5. R. H. Crawford, A. Stephan, A. G. Nellickal, A. V. Rajendra, and S. Palaniappan, "A simulation-based model for evaluating the performance of ready-mixed concrete (RMC) production processes," 2015.
6. P. G. Dunlop and S. D. Smith, "Development of a process documentation system for the house-building industry," Univ. Northumbria, Assoc. Res. Constr. Manage., 2002.
7. M. Galić and I. Kraus, "Simulation Model for Scenario Optimization of the Ready-Mix Concrete Delivery Problem," Sel. Sci. Pap. - J. Civ. Eng., Walter de Gruyter GmbH, vol. 11, no. 2, pp. 7–18, 2016.
8. T. Hong, C. Ji, and H. Park, "Integrated model for assessing the cost and CO_2 emission (IMACC) for sustainable structural design in ready-mix concrete," J. Environ. Manage., vol. 103, pp. 1–8, 2012.
9. H. Lai, X. Deng, and T.-Y. P. Chang, "BIM-Based Platform for Collaborative Building Design and Project Management," J. Comput. Civ. Eng., ASCE, vol. 33, no. 3, p. 05019001, 2019.
10. P. C. Lin, J. Wang, S. H. Huang, and Y. T. Wang, "Dispatching ready-mixed concrete trucks under demand postponement and weight limit regulation," Autom. Constr., vol. 19, no. 6, pp. 798–807, 2010.
11. H. Liu, J. C. P. Cheng, V. J. L. Gan, and S. Zhou, "A knowledge model-based BIM framework for automatic code-compliant quantity take-off," Autom. Constr., vol. 133, p. 104024, 2022.
12. M. Lu and H. C. Lam, "Simulation-optimization integrated approach to planning ready mixed concrete production and delivery: Validation and applications," Proc. Winter Simul. Conf., pp. 2593–2604, 2009.
13. A. G. Nellickal, A. V. Rajendra, and S. Palaniappan, "A simulation-based model for evaluating the performance of ready-mixed concrete (RMC) production processes," Living and Learning: Res. Better Built Environ., 49th Int. Conf. Archit. Sci. Assoc., 2015.
14. O. I. Olanrewaju, D. J. Edwards, and N. Chileshe, "Estimating on-site emissions during ready mixed concrete (RMC) delivery: A methodology," Case Stud. Constr. Mater., Elsevier Ltd, vol. 13, 2020.
15. S. Palaniappan, H. Bashford, K. Li, A. Fafitis, and L. Stecker, "Carbon emissions based on transportation for post-tensioned slab foundation construction: A production home building study in the greater Phoenix Arizona area," Int. J. Constr. Educ. Res., vol. 5, no. 4, pp. 236–260, 2009.
16. J. Parikh, M. Panda, A. Ganesh-Kumar, and V. Singh, "CO2 emissions structure of Indian economy," Energy, Elsevier Ltd, vol. 34, no. 8, pp. 1024–1031, 2009.
17. M. Park, W. Y. Kim, H. S. Lee, and S. Han, "Supply chain management model for ready mixed concrete," Autom. Constr., pp. 44–55, 2011.
18. S. Reichenbach and B. Kromoser, "State of practice of automation in precast concrete production," J. Build. Eng., Elsevier Ltd, 2021.
19. M. Research Services Section, "Extending the Delivery Time of Concrete Mixtures," Research Services, 2011.
20. M. Sandanayake, G. Zhang, and S. Setunge, "Estimation of environmental emissions and impacts of building construction – A decision making tool for contractors," J. Build. Eng., Elsevier Ltd, vol. 21, pp. 173–185, 2019.

21. S. D. Smith, "Modelling and experimentation of the concrete supply and delivery process," Civ. Eng. Environ. Syst., Gordon & Breach Sci. Publ. Inc, vol. 16, no. 2, pp. 93–114, 1999.
22. J. Talian, "Optimization of the Concrete Delivery and Placement Process Using a Simulation," Slovak J. Civ. Eng., Walter de Gruyter GmbH, vol. 21, no. 2, pp. 1–6, 2013.
23. T. M. Zayed and I. Minkarah, "Resource Allocation for Concrete Batch Plant Operation: Case Study," n.d.
24. J. Zhang, "Empirical study and risk assessment on ready mixed concrete industry," BMEI 2011 - Proc. Int. Conf. Bus. Manage. Electron. Inf., pp. 648–651, 2011.
25. S. Zhang, F. Pan, C. Wang, Y. Sun, and H. Wang, "BIM-Based Collaboration Platform for the Management of EPC Projects in Hydropower Engineering," J. Constr. Eng. Manage., ASCE, vol. 143, no. 12, p. 04017087, 2017.
26. Y. Zhang, M. Li, and Z. Liu, "Vehicle scheduling and dispatching of ready mixed concrete," Proc. 4th Int. Workshop Adv. Comput. Intell., IWACI 2011, pp. 465–472, 2011.