

PRODUCTIVITY ANALYTICS FOR CONSTRUCTION: USING FIELD DATA (RFID/IOT) TO IMPROVE LOOK-AHEAD PLANNING AND PPC

ANÁLISE DE PRODUTIVIDADE NA CONSTRUÇÃO: UTILIZAÇÃO DE DADOS DE CAMPO (RFID/IoT) PARA MELHORAR O PLANEJAMENTO PRÉVIO E O PPC

Article received on: 1/30/2026

Article accepted on: 4/30/2026

Mohamed Basham*

*University of Peradeniya, Peradeniya, Central Province, Sri Lanka

Orcid: <https://orcid.org/0009-0008-3361-3002>

bashamzee@gmail.com

The authors declare that there is no conflict of interest

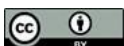
Abstract

The productivity of construction operations is subject to uncertainties in the workforce, e.g., missing resources, incomplete prerequisites, space congestion, and delayed recognition of deviations in the execution of planned activities. The Lean Construction philosophy, through the Last Planner System (LPS), is based on look-ahead planning and make-ready planning to increase the reliability of weekly commitments through Percent Plan Complete (PPC). Sensing and analytics technologies have experienced rapid growth in the period from 2020 to 2025. RFID, IoT, RTLS with BLE technology, equipment telemetry, and cloud analytics have enabled the possibility of transforming planning from “periodic reporting” to a sense-and-respond approach. However, digital monitoring is often used as a simple monitoring system with minimal influence on look-ahead planning and PPC learning. This paper is based on a systematic review of the evidence for productivity analytics in the construction industry from 2020 to 2025. The focus is on the utilization of data generated in the field of construction through IoT/RFID technology for look-ahead planning, make-ready planning, and PPC. The paper is based on the PRISMA 2020 criteria for transparent reporting [1]. This paper also benefits from recent systematic reviews on LPS automation [10], IoT technology in the construction industry [11, 12], BIM-IoT fusion technology [13], as well as empirical frameworks for real-time data-driven analysis in the construction industry [14] and deployable RTLS technology in the field [15].

Keywords: Construction Productivity. RFID. Iot. RTLS. BLE. Look-Ahead Planning. Last Planner System. Percent Plan Complete. PPC. Workface Planning. Analytics.

Resumo

A produtividade das operações de construção está sujeita a incertezas no canteiro de obras, como, por exemplo, falta de recursos, pré-requisitos incompletos, congestionamento de espaço e atrasos na identificação de desvios na execução das atividades planejadas. A filosofia da Construção Enxuta, por meio do Last Planner System (LPS), baseia-se no planejamento antecipado e no planejamento de preparação para aumentar a confiabilidade dos compromissos semanais por meio do Percent Plan Complete (PPC). As tecnologias de sensoriamento e análise tiveram um rápido crescimento no período de 2020 a 2025. RFID, IoT, RTLS com tecnologia BLE, telemetria de equipamentos e análise em nuvem possibilitaram a transformação do planejamento de “relatórios periódicos” para uma abordagem de “detectar e responder”. No entanto, o monitoramento digital é frequentemente utilizado como um sistema de monitoramento simples, com influência mínima no planejamento antecipado e no aprendizado do PPC. Este artigo baseia-se em uma revisão sistemática das evidências sobre análise de produtividade no setor de construção civil de 2020 a 2025. O foco está na utilização de dados gerados no campo da construção por meio da tecnologia IoT/RFID para planejamento prospectivo, planejamento de preparação e PPC. O artigo segue os critérios PRISMA 2020 para relatórios transparentes [1]. Este artigo também se beneficia de revisões sistemáticas recentes sobre automação do LPS [10], tecnologia IoT no setor de construção [11, 12], tecnologia de fusão BIM-IoT [13], bem como de estruturas empíricas para análise orientada por dados em tempo real no setor de construção [14] e tecnologia RTLS implantável no campo [15].



Palavras-chave: Produtividade na Construção. RFID. IoT. RTLS. BLE. Planejamento Antecipado. Last Planner System. Percent Plan Complete. PPC. Planejamento da Área de Trabalho. Análise de Dados.

1 INTRODUCTION

Construction is analogous to a distributed logistics system in which construction workers, construction materials, equipment, and information must be brought together at the workface in a timely manner in accordance with changing construction site conditions. When construction prerequisites are uncertain, construction workers idle, substitute work, and/or rework, resulting in productivity losses that are not easily quantifiable until schedule impact is evident.

Lean construction presents a different paradigm for managing construction projects by viewing planning as a production control system. The Last Planner System (LPS) places significant emphasis on collaborative planning and constraint removal in order to provide reliable commitments. The look-ahead planning horizon is typically 3 to 6 weeks and is intended to identify constraints in a timely manner so that construction tasks become “ready” well in advance of construction planning. PPC measures the percentage of planned construction tasks completed as planned and also supports learning by reason analysis. Industry guidelines describe LPS as a system for developing a predictable workflow by removing constraints in advance of disruptions in workflow. This review consolidates current evidence regarding the use of RFID/IoT field data for developing construction signals that inform look-ahead planning and PPC optimization in construction projects. It is written in accordance with the requirements for a Q1 operations and logistics journal by providing a clear conceptual model, transparency in methods, and actionability for managers in construction operations and construction projects.

2 AIM AND OBJECTIVES OF THE STUDY

Aim: The aim of the study is to synthesize the existing research on construction productivity analytics from the years 2020-2025, as well as develop an integrative framework on the ways in which RFID/IoT field data can be used for enhanced look-ahead planning and PPC through quantifiable control loops.

Objectives: The objectives of the study are as follows:

(1) To categorize the modalities of field data sensing used in productivity analytics, including RFID, RTLS, BLE, IoT environmental sensors, as well as equipment telemetry, and define the measures that can be quantitatively taken with each modality.

(2) To synthesize the data engineering approaches that align raw data with work packages, locations, as well as constraints, typically using BIM models.

(3) To compare the analytics approaches used in the quantification of productivity loss as well as constraint risk.

(4) To evaluate the integration approaches used in the alignment of the analytics with LPS processes, including look-ahead constraint screening, make-ready processes, as well as PPC reason coding.

(5) To propose a methodology blueprint as well as a research agenda for the deployment of the same in the industry.

3 REVIEW METHODOLOGY

3.1 Review design and reporting

The study aims to conduct a structured review study in a narrative synthesis format. The study aims to adhere to the PRISMA 2020 recommendations, which provide guidance on reporting a study on a structured review study, including the search strategy, as well as the rationale for conducting a narrative synthesis study [1]. Due to the diversity of sensors, metrics, and settings in use in projects, a meta-analysis is not feasible; hence, a narrative synthesis study will be conducted through a mapping of method to use case in look-ahead planning and PPC control.

3.2 Search strategy

A comprehensive search strategy will be conducted through the use of various databases such as Scopus, Web of Science, IEEE Xplore, ASCE Library, Google Scholar, etc., to obtain articles published between 2020 and 2025 using a variety of search terms such as “construction productivity” AND (“RFID” OR “IoT” OR “RTLS” OR “BLE” OR “wearable”); “look-ahead planning” OR “make-ready” OR “Last Planner” OR “PPC”; “constraint management” AND “automation”; “BIM IoT integration” AND “progress monitoring.” In addition, recent systematic reviews on IoT adoption [11,12], real-time monitoring [16], BIM IoT integration [13], and automation of LPS [10]. For a paper to qualify to be included in this study, it must qualify by meeting certain requirements such as being published between 2020 and 2025 and being a peer-reviewed journal/conference paper or a high-quality open report that measures productivity/progress/constraints by using field data and/or analytics in planning/control and providing methodological information to identify the modality of sensing, analytics, and evaluation method. Excluded from this study will be those that do not provide methodological information and opinion pieces, lean studies that do not use analytics, and those that are not in the construction industry context.

Table 1

Representative 2020–2025 evidence base for field-data-to-PPC integration.

Source	Study type	Focus	Key contribution	Implication for look-ahead & PPC	Ref
Agrawal et al. (2024)	Systematic literature review	Automation in LPS planning/control	Look-ahead has most automation functions; constraint mgmt central	Prioritize readiness/constraints over pure tracking	[10]
Radman et al. (2025)	8 case studies	Real-time data-driven project analysis (RealCONs)	Improves early delay identification and forecasting	Reduce data→decision latency for make-ready	[14]
Khazen et al. (2025)	Field deployment	BLE RTLS for indoor worker tracking	Deployable approach; practical considerations for sites	Use RTLS for congestion/flow, not surveillance	[15]
Musarat et al. (2024)	Systematic review + framework	IoT adoption barriers/benefits	Productivity and safety gains, but standardization/privacy barriers	Plan governance and protocol standardization	[11]

Khan et al. (2024)	Empirical adoption study	IoT effects on safety/efficiency	Links adoption factors to outcomes for site efficiency	Integrate sensing with management practices	[12]
Liu et al. (2025)	State-of-the-art review	BIM-IoT-GIS integration	Highlights interoperability and integration gaps	Use semantic mapping to work packages	[13]
Mengiste et al. (2023)	Method paper	Automating look-ahead using site conditions + GRU	Predicts task completion rates from site signals	Use predictive alerts for readiness risk	[19]
Lukacs et al. (2025)	Architecture paper	RFID/IoT + cloud data pipeline model	Shows integrated identifier→IoT→cloud design with diagrams	Reusable pipeline patterns for construction logistics	[17]

4 FOUNDATIONS: LOOK-AHEAD PLANNING, MAKE-READY, AND PPC AS CONTROL VARIABLES

“Look-ahead planning is a constraint discovery and readiness process.” Each of these operations is checked, and it checks for constraints such as design information, materials, access, approvals, manpower, equipment, etc. If there is a constraint, these operations go back into the look-ahead buffer and wait until constraints are removed. PPC is calculated by completed commitments divided by the number of planned commitments, and non-completions are analyzed by the presence of a systemic problem. An overview of automation in LPS, conducted in the year 2024, revealed that there were 50 automation functionalities in all stages of LPS, and the maximum number of automation opportunities were in look-ahead planning, such as constraint identification, readiness, knowledge reuse, etc. [10]. This is important while using productivity analytics, as most data will be interpretable as signals instead of “% complete.”

One of the implications is that the productivity analytics has to be in a position to provide the appropriate kind of information. For the look-ahead, the appropriate kind of information is: “What are the tasks that are constrained? What are the constraints that are missing? What is the time required for the tasks to be ready?” For the weekly, the appropriate kind of information is: “What is expected in terms of crew productivity? What is the amount of congestion? How likely are you to make commitments with the current conditions?” For the PPC, the appropriate kind of information is: “What is available to

help with learning? For instance, are there standardized reason codes so that you are not blaming the individual for the problem?”

5 FIELD DATA FOR PRODUCTIVITY ANALYTICS: SENSING MODALITIES AND WHAT THEY MEASURE

5.1 RFID and asset/material visibility

RFID is used for identification and event capture for materials, tools, and assets. It can be used for “did it arrive?” and “is it staged?”-type questions, which are important for “making ready.” Passive RFID tags are used for gate scans and asset verification in staging areas. Active RFID tags are used for more frequent tracking, though they are more costly. It is important that the data be linked to the work packages, such as “materials delivered for zone A work package,” as opposed to just inventory items.

5.2 RTLS/BLE and workforce flow

RTLS using BLE is another technology that is becoming popular for worker and resource location inside the facility. A 2025 deployable solution discusses the use of BLE RTLS, as it is common for the use case of “assisting the construction manager,” with implementation considerations for real-world sites as discussed in [15]. RTLS using BLE is important for productivity analytics, as it can be used for estimating time on task, travel, waiting, zone, and handoffs. However, this is still not enough, as the data needs to be linked to the “planned” for the work packages.

5.3 IoT environmental and equipment telemetry

The use of IoT sensors for the acquisition of data such as temperature, humidity, and dust levels is possible. This is important as a leading indicator for the improvement of productivity since the idle time for cranes could be an indicator of failure in the staging of materials, temperature could affect the productivity of labor and safety issues, and poor air quality could affect the productivity of labor for interior works. The study for the use

of IoT for safety and efficiency in the year 2024 examines the relationship between the factors for adoption and the outcomes. This is in support of the overall assertion that the use of IoT for the improvement of efficiency in the construction industry is possible as long as it is well integrated as discussed in [12].

5.4 Vision/point cloud and progress measurement

Although the focus of the current paper is the use of RFID and IoT, the field of construction productivity analytics is increasingly using 3D vision and point cloud data as part of the data analysis for the improvement of construction progress. Recent research in the area of smart construction monitoring has used a combination of point cloud data and real-time IoT sensors and indoor locationing for the improvement of construction site management [18].

6 DATA ENGINEERING: TURNING FIELD SIGNALS INTO PLANNING-READY INFORMATION

Data collected in the field is often dirty, incomplete, and lacks semantic context. Data engineering answers the question of whether the data collected by the sensors has actual managerial value.

6.1 Cleaning, fusion, and time alignment

RFID data may not be scanned, BLE location may not be accurate, and IoT sensors may not function or lose connectivity. In practice, data pipelines may need to filter out errors, detect anomalies, and cope with missing data. Sensor fusion is important for integrating material arrival (RFID), availability of workspaces (RTLS congestion), equipment usage (telemetry), and planned work (schedule/BIM).

6.2 Semantic alignment to work packages and constraints

The most critical aspect of the data integration pipeline is the alignment of the data with the relevant objects of interest for the construction planner. The most popular solution for achieving this is the integration of BIM and IoT. A recent SoA review of the integration of BIM, IoT, and GIS in the construction industry for the year 2025 highlights the potential of integrating BIM, IoT, and GIS in the construction industry, as well as the importance of data integration in the construction industry [13].

6.3 Governance: ownership, data rights, and access control

The data pipelines must also consider ownership and access control. Worker tracking is a privacy concern and may lead to resistance if the workers view it as a negative aspect instead of a positive one. Governance: Considerations for the system include “decision support for planning” instead of “worker scoring.”

6.4 Data structures that matter: work package IDs, locations, and constraint objects

The problem with data analytics is the structure of the data. For the sensing analytics domain, the structure of the data is based on device IDs. On the other hand, the structure of the data for the planning domain is based on the work packages. There is a need for a bridge between the two. This bridge has been provided by the use of data structures. There are three data structures that are important. One is the work package object, which is a data structure that has a unique ID and matches look-ahead planning and weekly work plans in terms of attributes such as start/finish date, crew, location, and prerequisites. The second one is the location object, which is a zone data structure that aggregates the sensor data, for example, floor/room/area structure. The third one is the constraint object, which is a data structure for prerequisites and has attributes such as status, owner, and due date. The area of LPS automation research that is relevant is that of readiness and constraints as areas of high value in automation, as shown in [10]. Thus, productivity analytics must include constraints as a first-class citizen and not just a note

in meeting minutes. This will allow us to measure make-ready performance, constraints closure rates, and types of repeating constraints. Data structures will also allow us to learn, as PPC reasons will be mapped to types of constraints, and we will be able to identify what types of unreliability are most prevalent and therefore target countermeasures. The integration of BIM and IoT has also led to a schema being developed to define the current state of affairs, which has been described as having a gap in terms of interoperability due to differing systems having differing identifiers, as shown in [13]. This is to be addressed through a “single source of identifiers” concept, which is to be achieved through a development of a list of IDs to a master list of work packages, as well as a requirement to integrate data to allow a mapping to a list of IDs to be available to allow sensor data to be immediately usable to look ahead on a screen due to it being grouped into objects that can be seen by the planner.

6.5 Data quality in harsh environments: practical controls for construction sensors

Construction sites are hostile environments for sensors. There are issues with metals, dust, water, radio interference, and constant reconfigurations. Issues with data quality manifest as missing data points, data drift, and spurious data. RTLS solutions include implementation considerations such as layout and signal reliability. For data quality in the construction environment, a robust data pipeline must include operational controls as well as algorithms. One such approach is “quality by design.” For RFID systems, this involves defining the points for the materials and the layout for the reader. For BLE RTLS systems, this involves the use of calibration and quality flags. For IoT systems, this involves monitoring the uptime and latency. Timestamps are also important for data quality and should ideally be performed at the source. This prevents ambiguity in the data. Another such control is the use of triangulation. One signal is not enough for making a high-stakes conclusion. For instance, the RFID system may detect the presence of materials. The RTLS system may detect congestion at the installation zone. The crew may not be present. The task may still not be ready. The use of fusion produces more robust data. This is especially true when each data source has its own level of uncertainty. Another such control is the use of “data readiness thresholds.” This involves the use of data completeness thresholds. For instance, the system may alert the user that the data for

the zone is not ready. This prevents the common failure mode of the user getting dissuaded by the presence of a few spurious data points and ignoring the data completely.

7 ANALYTICS FOR LOOK AHEAD AND PPC: INDICATORS AND MODELS

7.1 Descriptive and diagnostic indicators

The first analytics results that can be expected to come out of this system will likely be a set of leading indicators related to planning decisions, such as material readiness score per work package, zone congestion index, equipment availability index, etc.

7.2 Predictive alerts and replanning support

The next analytics results that can be expected to come out of this system would likely be a set of predictive models that can provide probabilities of task completions given current readiness and flow status. In a recent research study on look-ahead planning, automation is provided to support look-ahead planning, which uses site conditions and space utilization to predict task completion rates through sequence models [19]. This is not applicable to this problem, as it is related to RFID/IoT input; however, it does illustrate how this type of input can be utilized to support look-ahead planning rather than reporting.

7.3 LPS automation and constraint management

The importance of constraint management is also highlighted in automation-related literature. In a systematic review published in 2024 on the current state of the art of automating planning and control in LPS, it is highlighted how, in terms of current research being conducted on automation in look-ahead planning, constraint management, knowledge reuse, replanning, etc., look-ahead planning has the highest level of automation functionalities incorporated into it [10]. In terms of productivity analytics

results, it is highlighted how analytics results can include constraint management and validation, as opposed to productivity measures alone.

7.4 Productivity as flow: from output rates to variability and stability

A major finding of the research on lean production control is that productivity issues are often caused by variability issues. Two crews with the same average output rate may have vastly different reliability since one crew may have had issues with micro-stoppages due to missing prerequisites. Quantifying this variability is possible with data collected by the time-in-motion variation of the RTLS system, the idle bursts observed by equipment telemetry, and the repeated delays in material staging observed by the RFID system.

The analytics for the “Look-Ahead Forecasting” should focus on the flow. This could include:

- Percent of time crew is in the productive zone vs. time in travel and wait zones;
- Frequency and duration of crew work stoppages;
- Queue length for shared resources such as the hoist;
- Frequency of task handoffs without rework.

These are just a few examples of the types of data that could be provided for the “Look-Ahead Forecasting.”

7.5 Analytics for constraint prediction and “make-ready forecasting”

The most important prediction problem is not forecasting the completion of the project but rather forecasting the readiness failures for the “Look-Ahead Forecasting.” This could be referred to as “make-ready forecasting,” where the probability of the task being ready by the week for the “Look-Ahead Forecasting” is estimated given the current constraint statuses and other field data. This could include:

- Time since the constraints were first opened;
- Historical closure rates by constraint type;
- Supplier reliability;
- Zone congestion;

Crew availability.

8 INTEGRATION PATTERNS: EMBEDDING ANALYTICS INTO LOOK AHEAD AND PPC ROUTINES

8.1 Look ahead “readiness boards” and digital make-ready

One integration pattern that has been proposed is the concept of a readiness board. There is a readiness status and a evidence link such as “materials staged,” “access cleared,” “crew available,” and “design released.” RFID may be used for the readiness status of the materials. RTLS may be used for potential issues with access by highlighting congestion. Telemetry may be used for equipment availability.

8.2 Weekly work planning and commitment calibration

Field data may be used for the calibration of the commitments for the week. For example, accurate productivity rates may be obtained by using field data. Also, the data may be used to detect unstable conditions. For instance, if RTLS data indicates high levels of congestion in a zone, the commitment may be adjusted. Also, the data may be used to determine that the task should not be included in the plan because the materials are missing, as determined by the RFID data. The use of field data may reduce the amount of planned work that has a low probability of completion and may increase PPC by providing a better quality plan.

8.3 PPC reason coding with evidence

For PPC learning, the commitments that were not completed must be determined first. The use of field data may reduce the amount of subjective coding by providing the “why” for the non-completion of the commitment.

8.4 Implementation patterns: from pilot to scaled operations

Pilots are the dominant implementation pattern in the literature, while scaling out implies the need for a multi-stage deployment strategy.

Stage 1: Visibility - Implement limited sensing on one process (e.g., material staging) with analytics generating a small number of validated readiness indicators. Measure the usage of the indicators by planners in the process of conducting 'look ahead' meetings.

Stage 2: Control - Implement the indicators in the make-ready process with clear ownership, including a constraint register, due dates, and escalations. Measure constraint closure time and changes in PPC.

Stage 3: Learning - Standardize PPC reason codes, link reason codes to evidence, and use analytics to determine recurring root causes across projects. Update the standard work process (logistics, prefab packaging, access planning, etc.).

Stage 4: Ecosystem - Extend data integration upstream into the supply chain and downstream into commissioning, thereby creating a 'value chain' perspective on the process.

9 METHODOLOGICAL PITFALLS IN THE LITERATURE

Several pitfalls are common in the body of 2020-2025 literature.

(1) Ground Truth Ambiguity: The data on productivity is manually collected. This may not be consistent. This may cause the model to overfit the data.

(2) Pilot Bias: Most of the data is collected in the pilot phase. The pilot phase is conducted on a single project. The data may not be applicable to other kinds of projects.

(3) Data Fragmentation: The data may not be collected while integrating the sensing tools with the planning tools. This may not give an accurate idea of the impact on the look-ahead and the PPC.

(4) Ethics/Acceptability: The workers may be tracked. This may affect the trust levels.

(5) Metrics Mismatch: The optimization may be done for tracking instead of decision effectiveness.

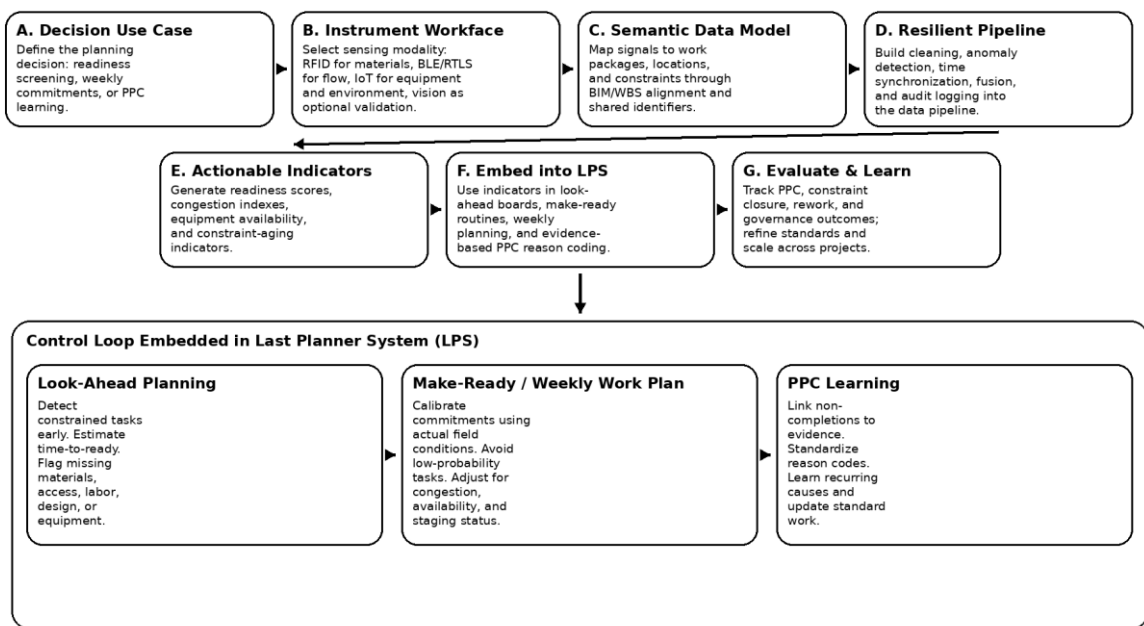
In order to test the effectiveness of the data, technical and operational metrics need to be used.

10 METHODOLOGY BLUEPRINT FOR FIELD-DATA-TO-PPC INTEGRATION

Figure 1

Figure. Seven-Step Blueprint for Field-Data-to-PPC Integration

Recreated with corrected spacing and text containment for Section 10 of the manuscript.



Corrected version with all text contained inside the boxes.

From the above synthesis, a seven-step blueprint is proposed for the integration of field data with the PPC.

Step A: Identify Decision Use Case: Decide the decisions that need to be integrated with the PPC. Decide the learning goals for the PPC.

Step B: Instrument the Workforce: Decide the right sensing modality for the decision use case. For example, for material and tools, the right modality is RFID. For congestion and flow, the right modality is BLE and RTLS. For equipment and environment, the right modality is IoT. 3D and vision may be used as an optional tool for validating the progress.

Step C: Develop a semantic data model. Map signals to work packages, locations, and constraints using BIM/WBS alignment and a naming convention.

Step D: Develop a resilient data pipeline. This should include filtering, anomaly detection, time synchronization, and audit logging. Architecture patterns for integrated RFID-IoT solutions can be useful sources for inspiration, e.g., identifiers, cloud storage, data capture, etc.

Step E: Develop actionable indicators. Develop readiness scores, congestion indexes, constraint aging, etc. Indicators can be enriched with predictive validity if evidence is available.

Step F: Embed into LPS processes. Indicators can be integrated into look-ahead readiness boards, weekly planning processes, etc. Evidence can be required for readiness claims. PPC reason coding can be used.

Step G: Evaluate and learn. Operational performance can be monitored (PPC, constraint closure, rework, etc.). Governance policies can be used for data privacy, access, security, etc.

11 RESEARCH AGENDA

Possible research topics for future studies include: (i) datasets for multiple projects that connect signals to LPS decisions such as look-ahead readiness, PPC, etc.; (ii) taxonomies for LPS constraints, reason codes, etc.; (iii) causal studies for disentangling sensing effects and process effects; (iv) privacy studies, especially those focused on workers, using participatory governance approaches; and (v) integrating with supply chains, especially prefabrication logistics, where RFID can be useful for reducing staging uncertainties. As LPS automation becomes more prevalent in the future, research can potentially contribute significantly to the field if it shows improvements in commitment reliability and flow, as well as sensing accuracy.

12 CONCLUSION

With the productivity analytics for the construction industry for the period of 2020-2025, the focus has shifted from the prototype stage of individual tracking to a more

holistic approach in the sensing analytics domain. There is proof that the data obtained by the RFID/IoT technology has the potential for the improvement of the look-ahead planning and PPC by converting it into a form that is more useful for the planning stage. The data obtained is semantically correct with regard to the work packages and the constraints. The data has the potential for use in the control process of the Last Planner System. There are systematic studies that show the potential for the use of the data for the automation of the look-ahead planning and the constraints [10]. There are also the real-time frameworks that show the potential for the reduction of the data-to-decision latency [14]. The blueprint for the methodology proposed in this study also shows the potential for the use of the data for the improvement of the reliable commitments and the productivity in the construction industry.

REFERENCES

- [1] Page, M. J., McKenzie, J. E., Bossuyt, P. M., *et al.* (2021). *The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ*, 372, n71.
- [2] Lean Construction Institute. (2025). *Last Planner System®* [página da web].
- [3] Sutisnawati, Y. (2025). *Internet of Things (IoT) innovation in supporting construction productivity. EJESet*.
- [4] Liu, X., *et al.* (2025). *BIM, IoT, and GIS integration in construction resource management: State-of-the-art review. Automation in Construction*.
- [5] Jayasundara, S. S., *et al.* (2025). *IoT-based real-time monitoring systems to enhance workers' safety in high-rise construction* [trabalho apresentado]. CIB World Building Congress.
- [6] Kim, J. Y., *et al.* (2025). *Integrated smart construction monitoring combining point clouds, IoT sensors, and UWB positioning. Sensors*, 25(13), 3997.
- [7] Gao, M. Y., Han, J., Yang, Y., & Tiong, R. L. K. (2024). *BIM-based and IoT-driven smart tracking for precast construction dynamic scheduling. Journal of Construction Engineering and Management*, 150(9).
- [8] Organiściak, P., *et al.* (2025). *Indoor real-time location system for resource localization in construction. Advances in Science and Technology Research Journal*.
- [9] Mengiste, E., Garcia de Soto, B., & Hartmann, T. (2023). *Automating lookahead planning using site appearance and space utilization. arXiv*.

- [10] Agrawal, A. K., Zou, Y., Chen, L., Abdelmegid, M. A., & González, V. A. (2024). *Moving toward lean construction through automation of planning and control in last planner system: A systematic literature review. Developments in the Built Environment, 18*, 100419. <https://doi.org/10.1016/j.dibe.2024.100419>
- [11] Musarat, M. A., et al. (2024). *Framework development for IoT in construction: A systematic review and synthesis. Results in Engineering.*
- [12] Khan, A. M., et al. (2024). *Internet of Things (IoT) for safety and efficiency in construction sites: Empirical relationships and outcomes.*
- [13] Liu, X., et al. (2025). *BIM, IoT, and GIS integration review: Applications, challenges, research gaps.*
- [14] Radman, K., Babaeian Jelodar, M., Lovreglio, R., Ghazizadeh, E., & Wilkinson, S. (2025). *Real-time tracking and analysis in construction projects: A RealCONS framework. Advanced Engineering Informatics, 67*, 103511. <https://doi.org/10.1016/j.aei.2025.103511>
- [15] Khazen, M., Nik-Bakht, M., Moselhi, O., & Dungen, J. (2025). *A deployable solution for indoor tracking of workers in construction using BLE RTLS. Journal of Information Technology in Construction (ITcon).*
- [16] *Real-time monitoring of construction sites: Sensors, methods and applications (comprehensive review).* (2022).
- [17] Lukacs, M., Toth, F., Horvath, R., et al. (2025). *Advanced digital solutions for traceability: NIRS, RFID, blockchain, and IoT integrated pipeline. Journal of Sensor and Actuator Networks, 14*, 21. <https://doi.org/10.3390/jsan14010021>
- [18] *Barriers and enablers of IoT adoption in construction: Privacy, cybersecurity, standards (review synthesis).* (2024).
- [19] *Construction IoT and BIM integration framework: Standardized protocols and modular devices.* (2025).
- [20] *Constraint management and plan reliability (lean construction): Empirical findings.* (2021–2024).
- [21] *Industry 4.0 and data-driven decision making in construction operations.* (2020–2023).
- [22] *Blockchain and data trust concepts for sensor data integrity in project systems.* (2020–2025).
- [23] *RFID applications for material tracking and logistics in construction supply chains.* (2020–2025).

- [24] *RTLS in construction: Positioning accuracy, multipath, and calibration considerations.* (2020–2025).
- [25] *BIM-based progress monitoring and production control integration review.* (2021–2025).
- [26] *Lean construction planning reliability and workflow stability in complex projects.* (2020–2025).
- [27] *Human factors in construction digitalization: Adoption, usability, and trust.* (2020–2025).
- [28] *Data governance and cybersecurity for connected construction sites.* (2020–2025).
- [29] *Metrics for production control: Variability, flow, and reliability indicators.* (2020–2025).
- [30] *Logistics-facing construction operations analytics: Value-chain visibility and constraint removal.* (2020–2025).