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Inventory Management Systems in the Construction Trade

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Abstract

This paper examines modern methods and information technologies for inventory management in the construction trade, aimed at optimizing working capital and ensuring uninterrupted supply to construction sites. The relevance of the study is determined by the fact that inventories of construction materials account for 60–65% of the total estimated cost of a project and maintain the Days Inventory Outstanding ratio at 50–60 days, which exerts significant pressure on contractors' liquidity and increases the cost of capital servicing. The objective of the work is a systematic analysis of the methods and information technologies for inventory management in construction trade—from classical replenishment models (EOQ, JIT) to the buffer-based DDMRP approach and cloud-based WMS/IoT platforms. The novelty of the study lies in the combined comparative review of traditional and modern tools: RFID and BLE identification, GPS marking of oversized materials, offline/online mobile scanning, DDMRP buffers, ML "short-horizon" forecasting, and integration of CO_2-footprint environmental metrics. A five-block architecture of an IMS is presented, and a practical "factory-to-site" case in Kyrgyzstan is described, demonstrating a 20–30% reduction in markup chains and a decrease in maintenance frequency at medical facilities. The main conclusions demonstrate that a modular platform with a continuous cycle—"identification – forecasting – replenishment – mobile warehouse – analytics – integration"—transforms seasonal and geographic uncertainty into a manageable asset: inventory accuracy increases to 95%, DDMRP buffers maintain a 99% service level, AI algorithms improve availability of 40% of SKUs without expanding storage footprint, and environmental metrics become part of financial reporting. This paper will be useful for executives and specialists in logistics, procurement, IT integration, and financial control within the construction industry.

Keywords: *Inventory Management, Construction Trade, EOQ, JIT, DDMRP, WMS, IoT, RFID, Machine Learning, Mobile Scanning, Environmental Metrics.*

INTRODUCTION

Inventories of construction materials are the largest consumer of working capital in the industry. Studies in digital logistics show that materials themselves constitute 60 to 65% of the total estimated cost of a project, and therefore any changes in their level immediately affect the contractor's liquidity and turnover ratio—in the Energy, Resources & Industrials sector, to which the construction business is statistically attributed, the Days Inventory Outstanding indicator remains around fifty to sixty days and continues to be the "heaviest" element of the cash cycle [1, 2].

When inventories are excessive, capital is "frozen" and its servicing becomes more expensive; when they are too low, downtime and penalties arise on site. The opposite extreme—shortages—was recorded by Infrastructure Australia's monitoring: due to price and logistics disruptions, approximately 7% of all planned work volume in the country is postponed, equivalent to project delays worth billions of dollars and direct losses to contractors [3].

The present article aims to systematically analyze which methods and IT solutions enable construction companies to escape the "excessive warehouse or empty-shelf" trap by reducing working capital without risking schedule disruptions. The focus is on a comparative overview of classical models (EOQ, JIT), the buffer-based DDMRP approach, and cloud-based WMS/IoT platforms, with the key conclusion being a practical set of metrics and steps necessary to achieve a balance between financial stability and uninterrupted site supply.

MATERIALS AND METHODOLOGY

The study of modern inventory management systems in construction trade is based on the analysis of 23 sources, including academic articles [1, 5, 8, 19], industry reports and analytical reviews [2, 4, 7, 17, 23], technical guides and white papers [14, 16, 18], implementation case studies on sites [6, 10, 13], publications in professional media [3, 9, 12], and web resources on environmental accounting and clinical research [15, 22]. Such coverage made it possible to consider

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scientific developments, practical implementation examples, statistical data, and market forecasts.

The theoretical foundation of the research comprised works on digital logistics and inventory management: BIM-WMS integration for decision support in construction [1], models of seasonal adjustment of production and inventories under climatic constraints [4], interrelations of BIM, Integrated Project Delivery, and Lean approaches [5], SKU rationalization methodologies [8], as well as reviews of the telematics market in construction equipment [17] and the impact of artificial intelligence on forecast accuracy and supply chain optimization [19, 23].

Methodologically, the study combined the following key approaches:

Comparative analysis of replenishment models: juxtaposition of classical EOQ and JIT methods, based on reorder points and delivery periodicity, with the buffer-based DDMRP approach [18] and ML "short-horizon" forecasting implemented in large-scale retail to improve availability of 40% of SKUs without warehouse expansion [13, 19].

Systematic review of identification and accounting technologies: comparison of barcodes, widely used in wholesale trade [14], with RFID tags and BLE beacons, increasing SKU accounting accuracy [11, 12, 16], as well as cases of GPS marking of oversized structures and IoT sensors on construction sites [10].

Content analysis of practical cases: assessment of economic losses from damage to façade glass in logistics and solutions to mitigate them [6], results of mobile scanning implementation on Android/iOS and ERP integration, reducing picking errors by 67% and accelerating cycle counts by 75% [14], and analysis of cloud-based WMS/IoT platform effectiveness according to Industrial Build News and Demand Driven Technologies [10, 18].

Analysis of industry statistics and market forecasts: evaluation of Days Inventory Outstanding in the Energy, Resources & Industrials sector and the impact of inventory levels on contractors' liquidity [1, 2], annual seasonal volatility of construction material output according to Eurostat [4], distribution network fragmentation in Europe and North America [9], and growth of the telematics market in construction equipment [17].

RESULTS AND DISCUSSION

Demand for construction materials exhibits pronounced annual volatility: Eurostat data for the West German production index have shown consistently low values in December–February, when frost and precipitation restrict field equipment operations, whereas the warm months generate a corresponding "peak" in production that must be absorbed by warehouse inventories [4]. Therefore, replenishment models for construction trade must a priori account for the project's weather phase and include buffer stocks; otherwise, the winter pause translates into cash-flow shortfalls in spring.

The second characteristic is the bulk and fragility of the product range. Heavy concrete, bulk aggregates, and long-length timber occupy significant volume at relatively low unit cost, so transportation accounts for 39–58% of all logistics costs and 4–10% of the final project price, as calculations have shown [5]. At the same time, sensitive items such as façade glass add risk: in the United States alone, damage in transit accounts for approximately 2% of market turnover—or USD 4.7 billion per year—and such damage is recorded in every 51st LTL shipment [6]. This is why the "keep more just in case it cracks" strategy remains widespread, even though Zero Waste Design estimates that 10–15% of purchased construction materials still become waste on site [7].

The third challenge is the breadth of assortment and the geography of dispatch points. Increasing product variety raises unit costs by 15–30%, while only 20–30% of SKUs typically generate profit, as portfolio analyses in the manufacturing industry have shown [8]. At the same time, the distribution market is highly fragmented: approximately 10,000 wholesalers in North America and 25,000 in Europe serve over 130,000 contractors, each with their own specifications and delivery schedules [9]. Without automated clustering and "end-to-end" inventory balancing across branches, such a network quickly loses transparency: buffer stocks are duplicated, and shortages are detected only at the time of shipment.

Finally, construction sites are "live" and distributed, so the system must operate in offline zones and capture movements at the point of occurrence. IoT inventory cases demonstrate that installing RFID readers at site entrances and BLE beacons on rack locations reduces shortages and accounting errors by an average of 32%, while automatic reconciliation with the bill of quantities cuts excess capital expenditures by nearly one third in the first year of operation [10]. Mobile client applications that synchronize with ERP when connectivity is restored allow the site supervisor to record cement issues directly at the mixer or receive the next pallet of tiles without paper waybills—critical for multi-site operations and high staff turnover.

Thus, seasonal unevenness, cargo mass and fragility, SKU proliferation, and site distribution form an interrelated system of constraints. Each imposes its requirements on forecasting, safety stocks, and the IT-solution architecture, and together they define the basic operational outline.

A modern IMS in the construction trade represents a modular platform in which all components—from primary recording to analytics—are interdependent. This linkage transforms seasonally volatile stock from a problem into a manageable asset: data on each material becomes a "common language" for logistics, procurement, site supervisors, and finance. Simultaneously, the physical aspect of inventory (pallets in the warehouse, containers on site, components in service vehicles) is continuously digitized and synchronized with the calculated data, providing a single source of truth across all management levels.

The foundation of this ecosystem is identification technologies. Barcodes remain the cheapest and most widespread tool, but in the segment of oversized and mixed shipments, they are increasingly supplemented by RFID tags and BLE beacons: these can be read without line of sight and scan a pallet or rack section in seconds. Field measurements by Auburn RFID Lab show that migration to RFID raises SKU accounting accuracy from ≈ 65% to 95% [11] and reduces inventory time by 90%—up to 20,000 items per hour [12]. For large-format positional materials (elevator shafts, ventilation sections), GPS marking is employed: a BLE sensor records the element's coordinates, and the data are merged into a unified map of the warehouse or construction site.

The next layer is forecasting and replenishment. For fast-turnover small items (fasteners, consumables), the classical EOQ model remains justified, but where the cost of error is high, companies switch to DDMRP buffers and the JIT method for concrete or thermal insulation deliveries. On projects with high demand variability, an ML forecasting overlay is added: a case from a large retail distributor showed that using AI algorithms for "short-horizon" forecasts covered 40% of the SKU range and annually increased product availability without warehouse expansion [13].

To materialize these calculations in "hardware," the IMS relies on a mobile warehouse. Android or iOS terminals enable receipt and issue directly on site: the site supervisor scans incoming goods from the delivery vehicle, the data immediately flows into the central accounting circuit, and the order is automatically closed in the finance system. Practice shows that implementing mobile scanning reduces picking and assembly errors by up to 67% and accelerates cycle counts by 75%—critical for distributed projects with dozens of storage points [14].

Above the operational level operates the analytical layer: the IMS calculates turnover, fill-rate, and days of supply, but in the construction trade, sustainability metrics—ranging from return rates to the CO_2 footprint of a batch—are increasingly being added. The "long tail" of SKUs generates the highest carbon footprint: indirect (Scope 3) emissions across the supply chain account for over 70% of a company's total profile, so inventory transparency becomes part of climate reporting as well as financial reporting [15].

All of the above functions are effective only with end-to-end integration: goods movements must be automatically reflected in the ERP, bills of quantities in the accounting system, and project changes in the BIM model. Thus, the five IMS functions form a continuous cycle: identification produces accurate input data, forecasting and replenishment transform them into an optimal material flow, the mobile warehouse closes the "office-field" gap, analytics convert results into manageable KPIs, and integration with corporate systems cements it all into a unified process. Only such a holistic understanding will enable construction companies to move from chronic "backlogs" and "bottlenecks" to predictable, capital- and environmentally-efficient logistics.

The first digital attempts to manage construction inventories were reduced to Excel spreadsheets: they provided a basic SKU list but could not synchronously reflect material movements between warehouses and sites. The transition to cloud SaaS platforms changed the situation, offering a unified database accessible online and offline. At the same time, the cloud opened API channels for connection to ERP, BIM, and mobile applications, laying the groundwork for subsequent technological advances.

At the identification level, barcodes have given way to RFID: the Auburn RFID Lab white paper records an increase in inventory accuracy from 63% to 95% after tagging and the near-complete elimination of manual counts [16]. When a tag is "embedded" in a pallet or a rebar rod, the system receives a continuous data stream, which is further enriched by IoT sensors and GPS signals.

It is precisely the Internet of Things that has extended the IMS beyond the warehouse: telematics modules on specialized equipment transmit engine hours, location, and fuel consumption in real time, enabling predictive maintenance forecasts and the automatic depletion of filters, oil, and parts upon wear. Industry-review analytics show that telematics usage reduces unplanned equipment downtime, fuel costs, and idle time, thereby increasing overall project productivity amid rising diesel prices and tight schedules, and the telematics market in construction equipment was valued at USD 1.30 billion in 2023 and is expected to reach USD 3.73 billion by 2032 [17], as shown in Figure 1.

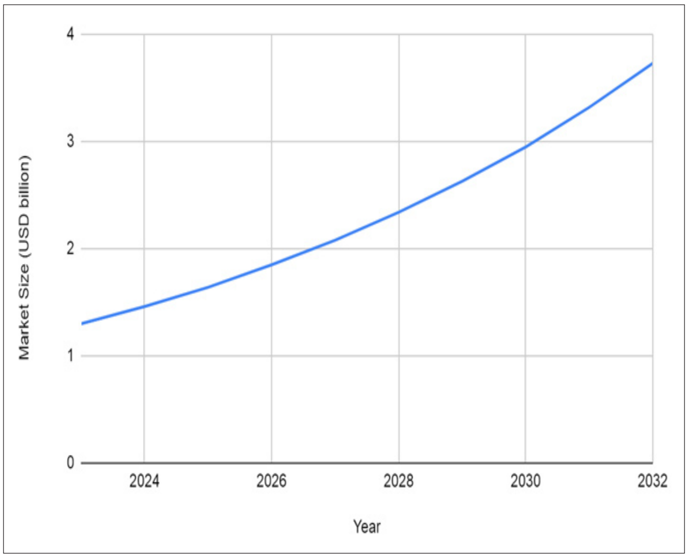

Fig. 1. Telematics in Construction Equipment Market Size [17]

For distributed contractors, this means that consumable stocks can be held closer to minimum levels, based on predictive signals rather than safety buffers.

The next evolutionary step is buffer management via DDMRP. Unlike traditional min–max or EOQ approaches, this method externalizes "uncertainty," dynamically recalculating green-yellow-red zones according to current demand and lead time. Intuiflow's practical results demonstrate seven-figure reductions in inventory dollar value while maintaining a 99% service level and shortening average production cycles by more than ten weeks, crucial for seasonal construction peaks [18]. The buffer layer is easily scalable in the cloud and directly fed by RFID and telematics data, closing the "plan-fact" loop in near real time.

The newest layer is artificial intelligence. Machine-learning models already exhibit statistically significant reductions in mean absolute material-forecast error compared to traditional methods, as confirmed by a 2025 study on AI's impact on forecasting accuracy and decision-making in supply chains [19]. Large distributors such as QXO appoint dedicated AI officers to integrate generative analytics into forecasting and optimization of inventories of pipes, lumber, and engineering systems, aiming to achieve manifold business growth in a saturated market [20]. According to [23], the AI-solutions market for supply-chain management was valued at USD 5.05 billion in 2023 and, at a CAGR of 38.9% from 2024 to 2030, may grow to USD 51.12 billion by 2030, as shown in Figure 2.

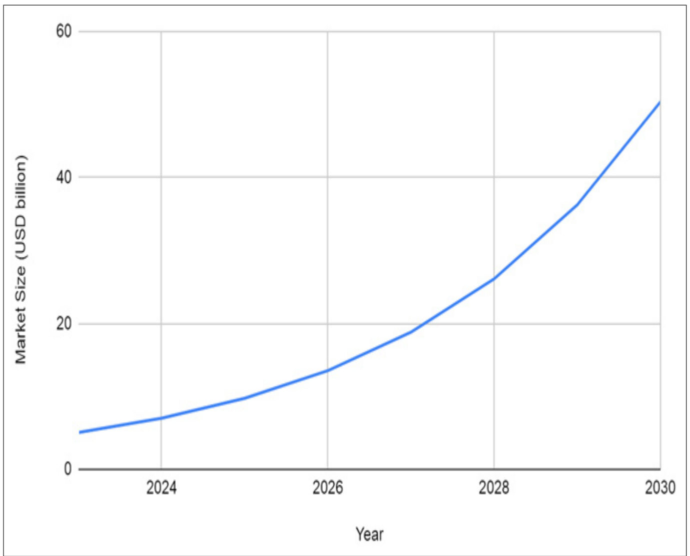

Fig. 2. Artificial Intelligence in Supply Chain Market Size [23]

Generative models not only refine supply plans but also create "what-if" scenarios for currency fluctuations, weather, or project-specification changes.

Thus, the journey from passive spreadsheets to a cloud-integrated platform has been marked by the progressive deepening of data and its analytical value. RFID and IoT have made inventories "visible," telematics have linked them to actual equipment operation, DDMRP has converted raw signal streams into flexible buffers, and AI has learned to extract forecasts and strategic insights from them. It is precisely this accumulation of technologies that explains why a modern IMS becomes not merely a warehouse module but the core of a construction project's financial resilience and competitive speed.

Supply-chain optimization should be built on a "project-to-warehouse" principle—that is, beginning not with stock accumulation but with precise demand calculation at the design stage. The key solution was the direct connection of European factories and Kyrgyz customers via a "factory-to-site" model. Practice has shown that eliminating intermediate distributors and transshipment warehouses reduces total chain costs by 20–30% by removing double markups and logistics operations, as confirmed by McKinsey's analytical report on value redistribution in the construction ecosystem [21], shown in Figure 3.

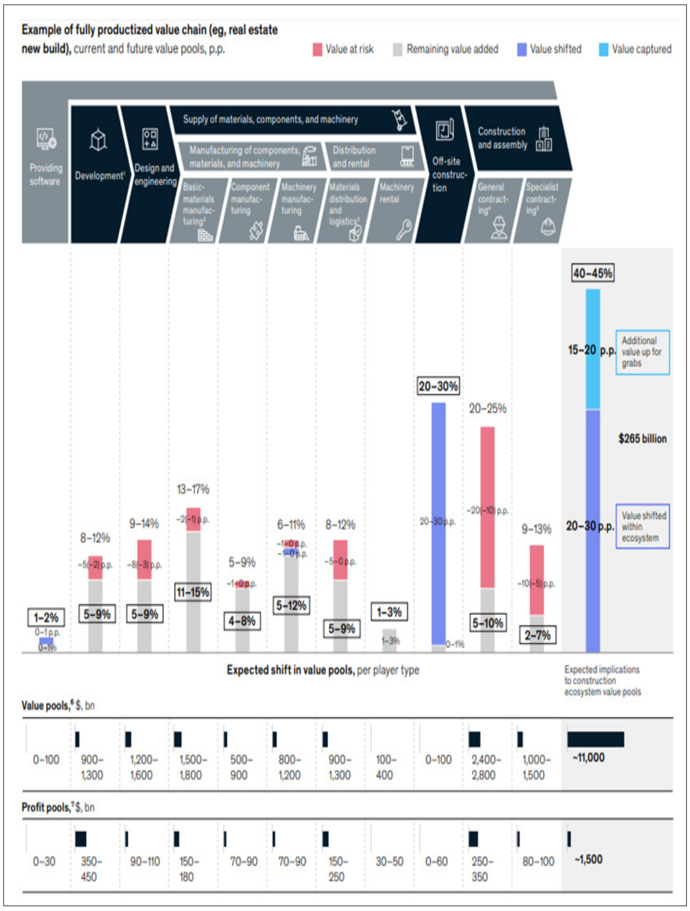

Fig. 3. Example of a fully productized value chain [21]

To ensure such a flow remained stable, the DDMRP buffer management was employed. For large batches of HPL panels, the yellow buffer zone held only a fifteen-day supply, and replenishment was triggered automatically from the ERP system as soon as on-site installation reached 50% of the scope. The first large-scale deployment occurred in healthcare: antibacterial PVC floors and ceilings were installed in fifteen hospitals where previous wooden coverings failed to meet sanitary standards. Studies show that by the fourth day after admission, resistant bacterial strains are detected in 58% of wards, spreading, among other pathways, via floors—so seamless vinyl surfaces reduced latent epidemiological risk and simultaneously eliminated the need to stock boards and paint for annual touch-ups [22]. The effect was twofold: freed working capital was redirected to new projects, and material expenses for the clinics decreased due to reduced maintenance frequency.

When demand increased, inventory management was shifted from a central warehouse to temporary on-site buffers, synchronizing delivery schedules with the buildings' BIM models. As a result, even peak loads—up to ten concurrent projects and 180 installers—were served without expanding permanent staff or immobilizing excess warehouse resources.

As the market embraced the innovative panels, acoustic ceilings, and antibacterials, competitors emerged—an indicator of the model's success: open access to the technologies accelerates the dissemination of sustainable practices and strengthens international ties. By forming a "data–buffer–delivery" chain without superfluous links, it demonstrated that even in a small economy it is possible to launch a fully functional IMS in which digital identification, forecasting, and direct flows generate not only financial benefit but also social impact—providing schools, hospitals, and business centers with safer, more durable environments.

Thus, a modern inventory management system in the construction trade is not merely a set of disparate tools but a unified digital loop in which identification, forecasting, buffer replenishment, mobile warehouse logistics, and end-to-end analytics operate in close concert. Such an integrated solution transforms seasonal volatility, material fragility and bulkiness, assortment breadth, and site distribution from traditional "bottlenecks" into manageable assets, reducing working capital and downtime risks. The implementation of cloud-based WMS/IoT platforms, DDMRP approaches, and AI forecasting ensures not only contractors' financial resilience but also enhances environmental responsibility through emissions transparency and inventory optimization.

CONCLUSION

In conclusion, a modern inventory management system in the construction trade addresses a constellation of interrelated constraints: seasonal demand unevenness, substantial material mass and fragility, broad SKU assortments, and distributed sites. Each of these factors requires specialized forecasting tools and safety stocks, and their combination demands a unified architecture capable of continuously processing and integrating data. Without automated identification, real-time accounting, and transparent information exchange among the warehouse, site, and office, it is impossible to achieve the optimal balance between schedule adherence and efficient working capital use.

The key element of such an ecosystem is a modular platform combining five functional blocks: identification (barcodes, RFID, BLE beacons, GPS), forecasting and replenishment (EOQ, JIT, DDMRP, ML algorithms), mobile warehouse (Android/iOS terminals), analytics (turnover, fill-rate, environmental metrics), and end-to-end integration with ERP, BIM, and financial systems. Thanks to this, seasonal volatility and geographic dispersion can be transformed from risks into manageable assets, and data on each material becomes a common language for logisticians, procurement specialists, site managers, and financiers.

Historically, the path from basic Excel spreadsheets to cloud SaaS platforms has been accompanied by deepening and refining of accounting data: the transition to RFID tags and IoT sensors increased inventory accuracy to 95% and reduced counting time by 90%, telematics linked inventories with equipment operation, and DDMRP buffer management together with artificial intelligence turned disparate signals into flexible dynamic-replenishment systems. The "factory-to-site" case in Kyrgyzstan demonstrated that direct linkage between factory and construction site can reduce chain markups by 20–30%, free up capital, and simultaneously improve building quality, from hospital wings to educational facilities.

Thus, a modern IMS in the construction trade is not limited to recording and warehousing operations: it is the core of financial resilience, environmental responsibility, and project competitiveness. The integration of digital technologies, analytics, and mobile solutions creates a predictable, capital- and resource-efficient model capable of scaling and transforming construction logistics into a sustainable, transparent value-creation chain.

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