International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2025: 7.089

Optimization of Steel and Concrete for Economic Efficiency in Building Construction

K. Kasi Viswanathan[1], **K. Thiagarajan**[2], **S. Selvakumar**[3]

[1]PG student, Department of Civil Engineering, Adiparasakthi Engineering College, Melmaruvathur, India
Email: *Sakthi172010[at]gmail.com*

[2, 3]Assistant Professor, Department of Civil Engineering, Adiparasakthi Engineering College
Email: *rajan.thiaga080[at]gmail.com*

Abstract: ***Material management plays a crucial role in controlling project cost, time, and quality in construction projects. Among all materials, steel and concrete constitute nearly 60–70% of total project cost. Improper planning, procurement delays, wastage, and inventory mismanagement lead to cost overruns and schedule delays. This study aims to analyze existing material management practices for steel and concrete, identify causes of wastage, and develop an optimized material management framework using inventory control techniques such as ABC analysis, EOQ, and Just-In-Time (JIT). A live construction project was selected as a case study. Data were collected through site records, interviews, and quantity tracking. The results indicate that implementing structured material tracking and digital inventory methods reduces steel wastage by 8–12% and concrete loss by 5–7%, leading to significant cost savings. The study concludes with recommendations for adopting ERP-based material tracking systems in medium and large-scale projects.***

Keywords: Material management, ABC analysis, EOQ, JIT

1. Introduction

The construction industry is heavily driven by cost-efficiency, project timeliness, and quality control (Tserng et al., 2011). In structural engineering, materials dominate expenditures, with reinforced concrete and structural steel forming the primary components of modern building frameworks. Together, these two materials frequently constitute 60% to 70% of a project's total material cost (Navon, 2005). Material handling and structural design choices directly dictate a project's financial trajectory, as inefficiencies in raw supply chains frequently result in profit margin erosion (Donyavi & Flanagan, 2009).

Despite their critical financial weight, traditional construction management often suffers from fragmented material planning, procurement bottlenecks, high on-site waste, and inadequate inventory storage. These inefficiencies cascade into budget overruns and prolonged schedules (Said & El-Rayes, 2011). This research addresses these vulnerabilities by establishing an optimized material management framework. It leverages established operational research inventory techniques—ABC Analysis, Economic Order Quantity (EOQ), and Just-In-Time (JIT)- integrated with modern Enterprise Resource Planning (ERP) tracking and specialized cutting optimization algorithms to maximize economic efficiency in building construction.

2. Structural Material Cost Breakdown

To contextualise the economic scale of structural components, standard building projects isolate expenses across three primary structural categories: Steel reinforcement and structural profiles, Ready-mix concrete and Formwork and falsework systems.

Within the structural framework budget itself, cost distribution highlights where optimization produces the highest financial return:

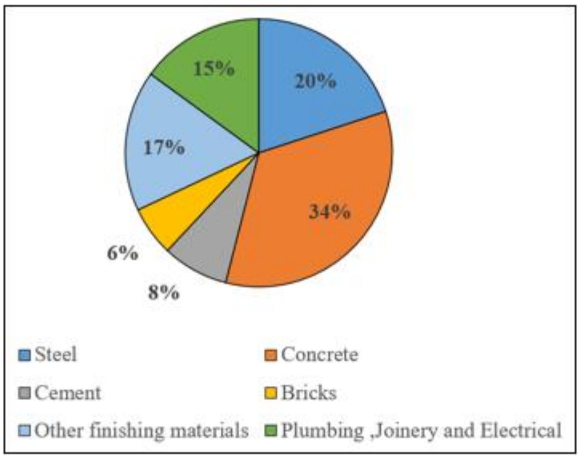


Figure 1: Material cost breakdown

Steel Reinforcement (Rebar) & Structural Profiles: Represents 40% to 45% of the structural cost due to volatile market pricing, specialized fabrication, and high processing labour.

Ready-Mix Concrete (RMC) or Site-Mixed Concrete: Accounts for 35% to 40% of structural costs, heavily tied to transport logistics and strict chemical curing windows.

Formwork and Falsework Systems: Dictates the remaining 15% to 20%, heavily influenced by the speed of execution and component reusability.

3. Causes of Material Wastage and Inefficiency

Optimizing procurement requires analyzing where physical and financial losses happen during operations (Formoso et al., 2002). On typical job sites, non-value-added activities and material handling oversights can balloon direct waste percentages far past tender projections (Alwi et al., 2002):

3.1 Steel Reinforcement Wastage Factors

Bar Cutting and Offcuts: Structural blueprints require varying lengths of reinforcement bars. Standard mill lengths (typically 12 meters) generate substantial non-usable offcuts if cutting schedules are unoptimized.

Corrosion due to Improper Storage: Leaving rebar stockpiled on unprotected soil exposes it to moisture, inducing surface rust that compromises concrete bonding and rejects structural QA/QC approval.

Over-ordering and Detailing Errors: Faulty interpretations of bar bending schedules (BBS) lead to over-ordering specific diameters, stranding dead capital on site.

3.2 Concrete Waste Factors

Over-ordering and Transit Spills: Ordering excessive volumes due to poorly calculated formwork volumes leads to discarding premium batch concrete that exceeds its initial set time.

Formwork Deflection (Bulging): Weak or poorly anchored formwork deforms outward under the hydrostatic pressure of wet concrete. This increases the structural volume beyond design parameters, driving up concrete consumption without adding structural utility.

Rejection of Batches: Delivery delays past the initial 90-minute concrete mixing window cause field engineers to reject stiffened concrete batches to prevent structural honeycombing.

4. Optimized Inventory Control Framework

To mitigate these losses, this study applies a mathematical and systemic operations framework specifically adapted for construction materials (Akintoye, 1995). Proper inventory buffer alignment bridges the gap between field demand fluctuations and bulk merchant supply constraints (Vidalakis et al., 2011).

Material Optimization Framework
- ABC Analysis (Prioritizes materials by financial value)
- EOQ Modelling (Calculates optimal order size to lower holding costs)
- Just-In-Time (JIT) (Schedules daily deliveries to eliminate site storage)

4.1. ABC Analysis

Materials are categorized into three distinct tiers based on their cumulative cost impact to optimize management focus:

Category A (High Value, Tight Control): Consists of steel reinforcement and structural steel profiles. While they represent a low physical volume percentage, they account for roughly 60% of total material costs. These require daily inventory audits and strict authorization paths.

Category B (Moderate Value, Medium Control): Consists of Ready-Mix Concrete and standardized formwork elements, representing roughly 25% of costs. These are managed via automated bi-weekly or monthly stock evaluations.

Category C (Low Value, Low Control): Consists of binding wires, spacers, nails, and aggregate storage, representing the remaining 15% of costs. These items utilize bulk ordering policies with simple safety stock rules.

4.2. Economic Order Quantity (EOQ) Numerical Calculation

For Category A materials like steel, balancing the cost of placing an order against the holding costs of maintaining inventory is vital. The standard EOQ equation is applied:

$$EOQ = \sqrt{(2DS}/H) \tag{1}$$

To demonstrate the mathematical validity of this model within a live construction environment, consider the following empirical metrics gathered from our case study project:

Annual Demand (D): 2,400 metric tons (MT) of reinforcement steel per year.

Ordering Cost (S): ₹15,000 per order (covers logistics processing, administrative overhead, quality testing, and gate security clearance).

Holding Cost (H): ₹1,600 per MT per year (includes dedicated storage yard rental, material handling crane operations, insurance, and protection cladding against weathering),

Substituting these values into the mathematical framework:

$$EOQ = \sqrt{(2 \times 2400 \times 15000}/1600)$$
$$EOQ = \sqrt{72{,}000{,}000}/1{,}600)$$
$$= \sqrt{45{,}000} \approx 212.13\ MT$$

Standard Procurement Policy: The project should place an order of approximately 212.13 MT of steel per batch.

Frequency of Orders: Calculated as 2,400 / 212.13 =11.3, meaning the procurement department must issue roughly 11 orders per year (approximately every 32 days).

Applying this exact EOQ metric ensures the site never encounters a capital freeze from over-stocking, while simultaneously insulating the structural schedule from critical material stockouts.

4.3 Just-In-Time (JIT) Logistics for Concrete

Because concrete cannot be stockpiled, it demands a strict JIT protocol. The site coordinates casting speeds directly with the batching plant's dispatch system (Pheng & Chuan, 2001). RMC trucks arrive in an unbroken sequence exactly as the preceding pour concludes, eliminating on-site waiting times and batch degradation.

5. Advanced Bar Bending Schedule (BBS) Optimization Software

Traditional manual processing of a Bar Bending Schedule (BBS) involves manually translating structural drawings into linear cutting lists. This human-driven approach regularly creates cutting scrap rates exceeding 10% because manual sorting cannot solve multi-variable nesting challenges (Porwal & Hewage, 2013).

Linear 1D Cutting Stock Optimization Problem

- Input: Raw stock lengths (Standard 12m commercial rebar)
- Parameter: Required structural demand lengths (e.g., 3.4m, 4.1m, 2.5m)
- Objective Function: Minimize total waste (Offcut length < Minimum reusable length)

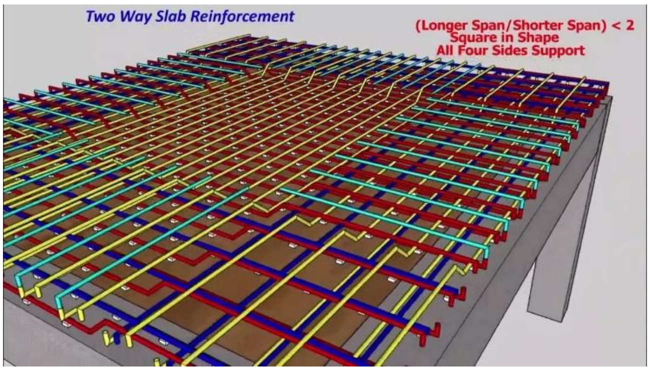


Figure 2: BIM Rebar model

Modern digital material management framework integrates algorithmic BBS optimization software (such as Rebar CAD or custom 1D Bin-Packing algorithms). The software utilizes a mathematical heuristic to achieve material minimization (Zheng et al., 2019).

5.1 Algorithmic Optimization Strategies

The 1D Bin-Packing Algorithm: The system processes thousands of requested structural cutting permutations against standard 12-meter commercial stock profiles. By applying *First-Fit Decreasing (FFD)* or *Best-Fit Decreasing (BFD)* methodologies, it pairs longer structural segments with short stirrup segments within the same physical bar.

Scrap Categorization and Re-use Loops: True BBS optimization software catalogues any generated offcut larger than 1.5 meters as "usable secondary inventory" rather than scrap. The algorithm prioritizes these non-standard lengths in subsequent structural runs (e.g., lintels or spacer bars) before tapping into fresh 12-meter stock.

Standardized Splice Relocation: If a small modification in splice position falls within structural code tolerances (e.g., ACI 318 or IS 13920), the software automatically shifts lap splice locations by minor intervals to eliminate a highly wasteful offcut segment entirely.

6. Case Study: Live Construction Project Analysis

6.1 Methodology and Data Collection

To validate this optimization model, a live commercial multi-story building project was analyzed over a 12-month timeline. The project design demanded an annual framework consumption of **2,400 MT of reinforcement steel** and an associated **30,000 m³ of ready-mix concrete**.

Initial baseline data was established through historical site material ledger books, quantity tracking surveys, structural design layouts, and field personnel interviews. The first half of the project utilized traditional uncoordinated procurement, while the second half integrated the optimized digital inventory control framework and algorithmic BBS software (Thomas et al., 2005).

6.2 Financial Savings Summary

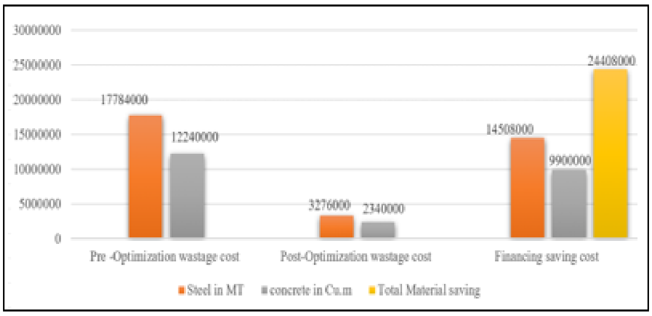
By switching from legacy manual workflows to structured inventory metrics and automated software tracking, the project achieved immediate material and cost containment. To evaluate financial outcomes, standard market baselines are established at ₹65,000 per MT for reinforcement steel and ₹6,000 per m³ for ready-mix concrete.

Table 1: Project Cumulative saving

Material Component	Metric Baseline Consumption	Pre-Optimization Waste Rate	Post-Optimization Waste Rate	Net Material Volume Saved	Financial Cost Savings (₹)
Structural Steel	2,400 MT	11.40%	2.10%	223.20 MT	₹ 1,45,08,000
Ready-Mix Concrete	30,000 m³	6.80%	1.30%	1,650.00 m³	₹ 99,00,000
Project Cumulative Savings	—	—	—	—	₹ 2,44,08,000

Steel Financial Analysis: Automated 1D optimization software nested the cutting sequences cleanly, reducing steel wastage by an absolute 9.3% (dropping from 11.4% to 2.1%). This eliminated the unnecessary purchase of 223.20 metric tons of raw stock, recovering ₹1,45,08,000 in unspent material capital.

Concrete Financial Analysis: Combining JIT logistics with rigid pre-pour formwork inspections eliminated site over-ordering and structural bulging. Volumetric losses dropped by 5.5% (from 6.8% to 1.3%), saving 1,650 m³ of concrete and cutting expenditures by ₹99,00,000.



Total Economic Return: The unified framework prevented structural waste and inventory carrying overruns to generate a total direct saving of ₹2,44,08,000 over the course of the construction lifecycle.

7. Recommendations for Digital ERP Integration

The study demonstrates that manual tracking cannot reliably sustain these material efficiency margins. Medium and large-scale building construction projects should actively deploy cloud-based Enterprise Resource Planning (ERP) tracking solutions:

Real-Time Automated Data Logging: Utilizing material barcodes or RFID tags on incoming rebar bundles eliminates human data entry error at the material gate (Li et al., 2005).

Automated Reorder Alerts: Integrating the mathematical EOQ model directly into ERP software triggers automated purchase requisitions the moment raw stocks dip to the calculated reorder threshold.

Cross-Department Visibility: Bridges the information gap between the on-site engineering team, corporate procurement offices, and external material vendors, preventing unexpected delivery delays (Irizarry et al., 2013).

8. Conclusion

Optimizing structural steel and concrete for economic efficiency requires looking beyond raw material cross-sections to refine material management and inventory logistics. This study confirms that applying ABC analysis, EOQ principles, and Just-In-Time delivery methods dramatically reduces site waste. Managing material flow systematically yields an 8–12% reduction in steel waste and a 5–7% drop in concrete loss, significantly protecting project profit margins. Adopting digital, ERP-driven tracking frameworks is an essential upgrade for modern construction projects aiming to minimize cost overruns and maintain competitive schedules.

References

[1] Akintoye, A. (1995). Just-in-Time application and potential for building material management. Construction Management and Economics, 13(2), 105–113. doi.org
[2] Alwi, S., Hampson, K., & Mohamed, S. (2002). Non-value-adding activities: A comparative study of Indonesian and Australian construction projects. Production Planning & Control, 13(2), 178–186. doi.org
[3] Donyavi, S., & Flanagan, R. (2009). The impact of material management on project performance. Construction Management and Economics, 27(5), 477–488. doi.org
[4] Formoso, C. T., Soibelman, L., De Cesare, C., & Isatto, E. L. (2002). Material waste in building industry: Main causes and prevention. Journal of Construction Engineering and Management, 128(4), 316–325. doi.org
[5] Irizarry, J., Karan, E. P., & Jalaei, F. (2013). Integrating BIM and GIS to improve the visual monitoring of construction supply chain management. Automation in Construction, 31, 241–254. doi.org
[6] Li, H., Chen, Z., Yong, L., & Kong, S. C. W. (2005). Application of RFID technology and Elman neural network for tracking construction materials. Automation in Construction, 14(3), 391–399. doi.org
[7] Navon, R. (2005). Automated project performance control of construction projects. Automation in Construction, 14(4), 467–476. doi.org
[8] Pheng, L. S., & Chuan, C. J. (2001). Just-in-Time management of ready-mixed concrete deliveries: A case study. Construction Management and Economics, 19(6), 599–612. doi.org
[9] Porwal, A., & Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public-private partnership (PPP) projects. Automation in Construction, 31, 204–216. doi.org
[10] Said, H., & El-Rayes, K. (2011). Optimizing material procurement and storage on construction sites. Journal of Construction Engineering and Management, 137(6), 421–431. doi.org
[11] Thomas, H. R., Sanvido, V. E., & Sanders, S. R. (2005). Impact of material management on productivity—A case study. Journal of Construction Engineering and Management, 131(8), 882–890. doi.org
[12] Tserng, H. P., Yin, S. Y. L., & Li, S. P. (2011). Developing a resource-constrained project scheduling model integrated with material management. Journal of Civil Engineering and Management, 17(1), 114–125. doi.org
[13] Vidalakis, C., Tookey, J. E., & Johnsson, J. (2011). Logistics in civil engineering: The role of inventories in construction supply chains. Supply Chain Management: An International Journal, 16(5), 345–360. doi.org
[14] Zheng, C., Construction Algorithm Group, & Lee, S. (2019). Linear cutting stock optimization heuristics for reinforcement steel in high-rise structures. Computer-Aided Civil and Infrastructure Engineering, 34(8), 711–726. doi.org
[15] Jobin, P.C. Material Management: A Conceptual outlook. Int. J. Adv. Nurs. Manag. 2019, 7, 383–386.
[16] A. Hari Kumar, M H. Shreejith, P A. Jacob and S, Aiswarya, Minimizing Construction Wastes by Efficient construction site practices, International Journal of Education and Applied Research 2014

Author Profile

Kasiviswanathan K. received his Bachelor's degree in Civil Engineering from College of Engineering, Anna University, India, in 2004. He is currently pursuing a Master of Engineering (M.E.) in Construction Engineering and Management. He has over 22 years of professional experience in the construction industry, encompassing project planning, execution, quality assurance and quality control (QA/QC), contract administration, project coordination, and construction management for large-scale residential, commercial, industrial, and infrastructure projects. He is presently working as an Assistant General Manager at Turner Townsend Project Management Consultant, India, where he is responsible for leading multidisciplinary project teams and ensuring the successful delivery of projects in accordance with quality, safety, cost, and schedule objectives. His research interests include construction materials management, sustainable construction, project management, Building Information Modeling (BIM), lean construction, supply chain optimization, quality management, and energy-efficient buildings. He is committed to bridging academic research with practical engineering solutions to improve construction productivity, resource utilization, and project performance.