

Multi-Agent Architecture

We will use three agents, each dedicated to a specific user and phase of the project:

1. The Trade-Off Analyst Agent (Pre-Construction/Value Finding)

- **User:** Project Managers, Estimators, Design Leads.
- **Focus:** Macro-level decision-making and identifying the optimal solution set.
- **Inputs:** Phase 1 JSON (Summary of all solutions) and Project Constraints (e.g., "Must finish in 120 days," "Cannot exceed \$X cost," "Maximize use of 3/4" bar due to supplier contract").
- **Behavior:**
 1. **Pareto Front Identification:** Automatically plot and identify the set of solutions that are non-dominated (i.e., no other solution is better in *all* metrics).
 2. **Constraint Filtering:** Filter the solutions that violate the user's hard constraints.
 3. **Recommendation Generation:** Explain the *trade-off* of the top 3-5 solutions.
 - *Example:* "Solution RS-04 is 5% cheaper than RS-08 but adds 7 construction days and increases the rebar volume for Story 5 by 15%, increasing your risk buffer."
 4. **Sensitivity Analysis:** Allow the user to adjust a variable (e.g., "What if the labor cost increases by 10%?") and re-rank the solutions instantly.

2. The Procurement & Logistics Agent (Pre-Construction/Just-in-Time)

- **User:** Procurement/Purchasing Manager, Logistics Manager.
- **Focus:** Converting the chosen solution into actionable purchase orders and delivery schedules.
- **Inputs:** Chosen Solution ID from the Trade-Off Analyst, Phase 2 JSON (Detailed metrics), and Real-Time Market Data (e.g., steel mill lead times, supplier price lists).
- **Behavior:**
 1. **JIT Schedule Generation:** Based on the construction schedule and the chosen solution's bar breakdown (from Phase 2 data, like the `vigas.json` content), generate a **phased procurement schedule** to minimize on-site inventory, adhering to the Least Responsible Moment (LRM) framework.
 2. **Consolidation Optimization:** Identify opportunities to *combine* material orders across different elements or stories that use identical bar lengths/diameters, simplifying vendor communication.
 3. **Waste Optimization Report:** Use metrics on cut lengths and splice lengths (from Phase 2) to generate a report detailing potential material waste, allowing the fabricator to optimize their cut lists.

3. The Field Adaptability Agent (Construction/Risk Mitigation)

- **User:** Site Superintendent, Foreman, Quality Control (QC) Inspector.

- **Focus:** Real-time problem-solving and maintaining construction momentum.
- **Inputs:** Chosen Solution ID, Phase 2 JSON (Detailed metrics), and Current On-Site Conditions (e.g., "Rebar delivery delayed," "QC issue with splice length in V-1585").
- **Behavior:**
 1. **Risk Flagging (Proactive):** Automatically alert the team about elements with a high **Constructability Index** (from Phase 2 data) before they start work on that story, suggesting simplified alternative solutions as backups.
 2. **Crisis Response (Reactive):** If a problem occurs (e.g., shortage of 7/8" bar), the agent immediately queries *all* solutions (Phase 1) to find the fastest/cheapest **substitute solution** that minimizes reliance on the scarce material.
 3. **Mixed-Solution Recommendation:** For a last-minute change affecting a single floor, the agent can recommend switching **just that floor** to a different solution (e.g., using Solution A for Floors 1-5 and switching to the simpler Solution B for Floor 6), recalculating the *net* project cost and schedule impact in real-time. This is the **most disruptive capability** and needs clear communication.

StructuBIM Agentic Workflow

This workflow is divided into three major stages, corresponding to the agents' primary focus: **Optimization**, **Implementation**, and **Adaptation**.

1. The Trade-Off Analyst Agent (T-OAA) — The Optimization Stage

The T-OAA is responsible for data-driven selection of the best reinforcement solution (RS) set.

Step	Action	Data Source	Output/Result
1. Ingestion	T-OAA ingests all available Phase 1 JSON files.	Solutions_Summary.json	Complete dataset of N fundamental RS metrics (Cost, Duration, Weight, Index).
2. User Input	User (e.g., Project Manager) defines Hard Constraints (e.g., Budget Max, Schedule Max) and Optimization Goal (e.g., "Weight reduction is 2x more important than speed").	User Input	Weighted objectives and filtering criteria.

3. Filtering	T-OAA filters the N solutions, removing any that violate the Hard Constraints.	Phase 1 JSON	A reduced set of Feasible Solutions .
4. Pareto Analysis	T-OAA performs Multi-Objective Optimization (MOO) to identify the Pareto Front (non-dominated solutions) based on the weighted objectives.	Feasible Solutions Set	The Optimal Solution Set (e.g., 5 best trade-off points).
5. Recommendation	T-OAA generates a narrative report detailing the pros and cons (trade-offs) of the top 3-5 solutions from the Optimal Solution Set.	Optimal Solution Set, Plot Image	Final Recommendation: User selects one or more Primary Solutions (RS-P) for the project.

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2. The Procurement & Logistics Agent (P&L-A) — The Implementation Stage

The P&L-A transforms the chosen solution into an executable JIT delivery plan.

Step	Action	Data Source	Output/Result
1. Solution Retrieval	P&L-A retrieves the detailed data for the chosen Primary Solution (RS-P) .	<code>Solution_[RS-P]_Detailed.json</code> (Phase 2)	Complete material breakdown per element/story.
2. Schedule Alignment	P&L-A integrates the construction Master Schedule with the detailed material breakdown.	Phase 2 JSON, Master Schedule	Material needs timeline linked to construction milestones.

3. JIT Optimization	P&L-A applies the Lean Least Responsible Moment (LRM) framework to the timeline, calculating the latest date each specific rebar lot can be ordered and delivered to minimize on-site inventory (buffer).	Calculated Timeline, Supplier Lead Times	Phased Delivery & Procurement Schedule (JIT Plan).
4. Logistics Grouping	P&L-A aggregates material requirements by bar diameter, length, and element type (e.g., beams, columns) to create optimized purchase orders and reduce the number of discrete supplier/fabricator transactions.	Phase 2 JSON	Final Purchase Order List and Logistics Plan.

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3. The Field Adaptability Agent (F-AA) — The Adaptation Stage 🚧

The F-AA provides real-time risk mitigation and solution switching for site execution.

Step	Action	Data Source	Output/Result
1. Proactive Risk Scan	F-AA reviews the Constructability Index for the current and upcoming stories (from Phase 2 data).	Phase 2 JSON (RS-P)	Constructability Alert: Flags specific elements (e.g., V-1585 in vigas.json) requiring extra planning/labor.
2. Constraint/Crisis Trigger	A site event occurs: A. Material shortage/delay OR B. On-site quality/constructability issue.	User Input (Site Report)	Identification of the specific element/story and the constraint violation.
3. Alternate Solution Query	F-AA queries the Phase 1 Summary for the best alternative solution that <i>solves</i> the constraint (e.g., one that uses a different, available bar diameter).	Phase 1 JSON (All solutions)	A list of potential Alternate Solutions (RS-A) for the affected element/story.

4. Net Impact Analysis	F-AA calculates the immediate impact of switching to the Alternate Solution (RS-A) <i>just for the affected area</i> (e.g., Floor 5).	Phase 1 & 2 JSON	Decision Metrics: Net change in total project cost, schedule, and material consumption.
5. Adaptive Recommendation	F-AA provides the recommended course of action.	Net Impact Analysis	Actionable Directive: "Switch Floor 5 to Solution RS-12, saving 3 days on fabrication and costing an extra \$5,000 in steel."