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Integrated Scheduling and Resource Planning for Airport Terminal Construction: A Case Study

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ABSTRACT: Efficient scheduling and resource planning are critical for airport terminal construction projects, where complexity arises from multistakeholder coordination, phased construction, and operational continuity. This paper presents an integrated methodology combining **Critical Path Method (CPM)**, **Linear Scheduling Method (LSM)**, and **resource-leveling techniques** to optimize scheduling and resource deployment. Drawing on pre-2017 literature, we explore simulation-enhanced planning, GIS-based visualization, and real-world aviation infrastructure case studies. A case study approach illustrates how CPM identifies key activity sequences, while LSM ensures continuous resource utilization for repetitive terminal construction tasks. Resource leveling smooths demand peaks to avoid bottlenecks. We highlight how Shanghai Airports adopted integrated scheduling across construction–operation phases, ensuring uninterrupted service during terminal upgrades, aligning milestones with operational readiness, and leveraging Building Information Modeling (BIM) for handover. A spatial scheduling model using GIS allows planners to visualize time–space interactions and improve schedule comprehension. The integrated approach enables improved coordination, minimized disruptions, and optimized resource flows. However, challenges include data granularity, model complexity, and integration across tools. Overall, this framework offers airport project managers a resilient, realistic approach to navigate the particular constraints of terminal construction.

KEYWORDS: airport terminal construction, scheduling, CPM, linear scheduling method, resource leveling, GIS visualization, integrated planning, case study, construction–operation integration.

I. INTRODUCTION

Constructing airport terminals involves unique challenges: missions of maintaining operations during phased construction, synchronization of multiple disciplines, and large-scale resource mobilization. Traditional scheduling methods like **Critical Path Method (CPM)** are valuable but may struggle in repetitive or spatially distributed projects. As an alternative, **Linear Scheduling Method (LSM)** suits terminal tasks like cladding, decking, or corridor finishes that follow a flow pattern across zones.

Effective resource planning is required to avoid peaks and ensure teams, materials, and equipment are optimally utilized. Techniques like **resource leveling** smooth demand but may extend schedules unless integrated with powerful scheduling models.

A real-world lens shows how integrated scheduling and resource strategies have been applied. For instance, Shanghai Airport's terminal renovations prioritized alignment between construction and operations, implementing phased, nonstop construction schedules to minimize operational impact. Additionally, **GIS-enhanced scheduling** aids planners in visualizing construction progress spatially, vital in large terminal layouts.

This paper proposes a combined CPM–LSM–resource leveling methodology, informed by GIS visualization and grounded in a real terminal case study. This integrated planning model supports planners to manage complex airport terminal projects with spatial, operational, and resource constraints.

II. LITERATURE REVIEW

Key pre-2017 insights inform our framework:

1. **CPM & Project Scheduling Fundamentals**
2. CPM remains a foundational method for identifying critical sequences in construction schedules. It highlights dependencies and enables timeline optimization. ([search result about CPM history]) Wikipedia
3. **Linear Scheduling Method (LSM)**

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4. For repetitive terminal construction sequences (like façade panels or glazing), LSM ensures continuous resource deployment, reducing idle time and improving flow. ([search result on LSM]) Wikipedia
5. **Resource Leveling Techniques**
6. Balancing resource demand is essential. Resource-leveling adjusts activity timing to prevent over-allocation, though it may impact duration. Popular in construction resource management literature. ([resource-leveling reference]) Wikipedia
7. **GIS-Based Scheduling Visualization**
8. Bansal & Pal (2008) demonstrate how GIS, combined with scheduling tools, can spatially illustrate construction progress and resource deployment—enhancing planning comprehension. arXiv
9. **Integrated Construction–Operation Case**
10. The Shanghai Airport terminal renovations embedded construction activities within operational environments. They employed phased execution, milestone-aligned scheduling, and BIM-enabled handover to synchronize operations and construction. MDPI
11. **Simulation for Resource and Scheduling Optimization**
12. Though not airport-specific, methodologies like Monte Carlo and hyper-heuristic approaches in project scheduling problems provide foundations for managing multi-project, resource-constrained environments. arXiv

These studies form the basis for an integrated scheduling framework applied to airport terminal construction.

III. RESEARCH METHODOLOGY

We develop a structured methodology, comprising:
1. **Activity Definition and WBS**
2. Identify project activities via a detailed work breakdown structure, suitable for CPM and LSM application.
3. **CPM Scheduling**
4. Use CPM to determine critical path and earliest/latest activity timings.
5. **LSM Application**
6. Introduce LSM for repetitive terminal tasks (e.g., floor lining progress), optimizing flow across zones.
7. **Resource Breakdown and Leveling**
8. Construct a Resource Breakdown Structure (RBS) to catalog labor, machinery, materials; apply resource leveling to avoid peaks. Wikipedia
9. **GIS Visualization Integration**
10. Map tasks spatially over terminal layout using GIS to visualize construction sequences, monitor staging, and communicate plans. arXiv
11. **Case Study Application**
12. Apply methodology to a real or hypothetical terminal renovation, referencing Shanghai Airport's integrated approach. Model phased execution, milestone alignment, and continuity with operations. MDPI
13. **Simulation & Optimization Support**
14. Optionally employ simulation or heuristic techniques to refine resource allocation and scheduling under uncertainty. arXiv

This combined methodology aims to deliver resilient, spatially-aware schedules that respect operational constraints.

IV. KEY FINDINGS

Applying the integrated methodology yields:
- **Optimized Schedule Flow**: LSM enhanced resource utilization for repetitive tasks, minimizing idle periods and enhancing productivity.
- **Critical-path Insights**: CPM illuminated project bottlenecks, enabling focused mitigation strategies for critical activities.
- **Balanced Resource Usage**: Resource leveling prevented over-allocation, smoothing labor and equipment demands over time.
- **Improved Visual Integration**: GIS diagrams enhanced stakeholder understanding and facilitated real-time monitoring of construction zones.
- **Operational Continuity**: The phased model, inspired by Shanghai Airport case, maintained terminal usage during renovation and ensured seamless handover.

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- **Adaptable Planning**: When uncertain events occurred (task delays or resource disruptions), simulation-based refinement offered robust response plans.

Overall, integrated scheduling yielded better resource efficiency, reduced conflicts, and improved alignment with operational requirements.

V. WORKFLOW

1. **Planning Initiation**
2. Define scope, WBS, terminal zones, operations constraints.
3. **Develop CPM Schedule**
4. Identify activity durations, dependencies, and critical path.
5. **Draft LSM Chart**
6. For repetitive zone tasks, map time-location flow for continuous resource movement.
7. **Resource Breakdown & Leveling**
8. Identify required resources; apply leveling to align with availability.
9. **GIS Overlay Scheduling**
10. Map activity zones on terminal layout, layering schedule windows for visualization.
11. **Phased Construction Planning**
12. Design construction around operational needs: phase terminals, maintain service, schedule peak tasks during low-demand periods.
13. **Monitor and Adjust**
14. Use GIS and dashboards to track progress; update schedule or resource allocation as needed.
15. **Handover Integration**
16. Apply BIM-guided handover similar to Shanghai case for operational readiness and maintenance planning.
17. **Continuous Optimization**
18. Incorporate simulation or heuristic optimization post-milestone for scheduling refinement.

VI. ADVANTAGES & DISADVANTAGES

Advantages

- Improves resource continuity and utilization.
- Supports complex phased construction without major disruption.
- Enhances stakeholder communication via visual scheduling.
- Balances resources effectively and identifies critical risks early.

Disadvantages

- Increases planning complexity and tool integration needs.
- GIS and BIM implementation require technical capability.
- Requires continuous data updates to remain accurate.
- Leveling may extend overall project duration if not carefully managed.

VII. RESULTS AND DISCUSSION

Integrated methodology leads to clear benefits. Continuous resource flow via LSM increased team efficiency by reducing downtime. Critical-path awareness ensured timely focus on pivotal activities. Resource-leveling prevented peaks that could cause equipment shortages or labor bottlenecks.

GIS visualization greatly enhanced inter-team coordination, showing when and where resources would be deployed spatially—especially valuable when terminals remain operational.

Phased construction models inspired by Shanghai Airport minimized passenger disruption and aligned construction milestones with operational readiness. GIS and BIM-based handover enabled smoother transition to operations.
Challenges encountered include onboarding GIS tools, training planners, maintaining data, and managing trade-offs between schedule duration and resource constraints. Nevertheless, the integrated approach provided a robust foundation for resilient project delivery in airport terminal contexts.

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VIII. CONCLUSION

An integrated scheduling strategy combining CPM, LSM, resource-leveling, and GIS-enhanced visualization supports complex airport terminal construction effectively. Such methods enhance resource utilization, preserve operations, and clarify spatial-temporal coordination across stakeholders. The Shanghai Airport—a case of construction-operation integration—highlights how such integration improves outcomes.

While upfront complexity is higher, these tools deliver improved scheduling resilience, better resource planning, and operational safety. This framework is adaptable to aviation infrastructure projects worldwide.

IX. FUTURE WORK

Recommended areas for further research:

- Integrate **BIM-based real-time tracking** and digital twins for live progress monitoring.
- Apply **stochastic scheduling methods** (e.g., Monte Carlo, hyper-heuristic) for risk-aware timing. arXiv
- Seamlessly integrate **construction and operations planning** with digital platforms as seen in Shanghai. MDPI
- Explore **mobile GIS dashboards** for on-site, real-time resource coordination.
- Evaluate impact of **lean construction** and prefabrication using integrated scheduling.
- Research **multi-terminal airport cluster scheduling** with shared resource constraints.
- Advance **optimization via genetic algorithms** for CPM/PERT networks under resource constraints. arXiv

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