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# CASH FLOW MONITORING DURING THE CONSTRUCTION OF INFRASTRUCTURE PROJECTS

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## Abstract

Delivery of infrastructure projects depends on balancing key constraints of time, cost, and scope. In large linear infrastructure projects such as railways, this balance is especially challenging due to complex activity sequences, significant upfront procurement requirements, and progress-based payment systems. Poor integration between scheduling and financial planning often results in cash flow problems, delays, claims, and budget overruns. Although many cash flow forecasting models exist in the literature, most are mainly theoretical and lack strong connections to actual scheduling decisions during project execution. In real-world practice, contractors, particularly on railway infrastructure projects, often modify schedules to accelerate early cash inflows by procuring expensive materials in advance. While these strategies might improve short-term liquidity, they can also disrupt execution processes, create a misleading view of physical progress, and increase financial and contractual risks. This study examines how construction scheduling affects cash flow through a detailed case study of a railway infrastructure project completed under FIDIC Red Book contract conditions. Several scheduling scenarios are analyzed and compared to evaluate their financial and operational impacts. The results demonstrate that schedules aligned with actual physical progress led to smoother, more predictable cash flow profiles, lower financial risk for both contractors and clients, and greater resilience to delays.

*Keywords: construction scheduling, cash flow management, infrastructure projects, railway construction, S-curve analysis, FIDIC contracts*

## 1 Introduction

The integration of construction scheduling and cash flow management is critical to the success of large-scale infrastructure projects. Construction schedules determine the sequence, duration, and resource allocation of activities, directly influencing the timing of project expenditures and payments. Effective synchronization of schedules with financial resources is therefore essential to sustain productivity, avoid delays, and maintain contractors' financial stability. Cash flow reflects the temporal distribution of project expenditures and revenues. While outflows are driven by activity cost profiles embedded in the schedule, inflows are governed by contractual payment mechanisms such as milestone or progress payments. Imbalances between inflows and outflows may create liquidity constraints, requiring external financing or disrupting projects. Despite extensive research on cash flow forecasting, most existing approaches rely on model-driven techniques that treat the schedule as static and do not explicitly examine how alternative scheduling strategies affect cash flow dynamics. To address this limitation, this study adopts a schedule-oriented, scenario-based approach to evaluate how different construction scheduling strategies influence project cash flow patterns.

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The analysis is conducted on a segment of the railway Corridor X project between Fushe Kosovo and Mitrovica, where three scheduling scenarios are assessed in terms of their corresponding cash flow implications.

## 2 Literature review

Recent journal literature provides limited discussion on the explicit alignment of construction schedules with cash flow management; therefore, this study draws on selected publications from the past three decades. The reviewed studies address several interrelated themes: scheduling as a driver of cash flow, cash flow as a control mechanism for schedule performance, the effects of delays and variations, the contractor's cash flow profile, and the integration of schedule and cost planning in linear infrastructure projects [1, 2]. The literature indicates that unrealistic activity durations, inefficient sequencing, and suboptimal resource allocation can significantly distort cash flow patterns and intensify financial pressure, even when total project costs remain unchanged [3]. Construction scheduling directly determines the timing of expenditures for labor, materials, equipment, and subcontractors, while adequate cash flow enables procurement, workforce mobilization, and corrective actions. Conversely, insufficient liquidity constrains production capacity and may delay project execution. Delays and variations further compound this interaction by modifying activity sequences, extending durations, and disrupting payment schedules, often generating a cycle in which reduced cash inflows exacerbate schedule delays [4-7]. This interaction is particularly critical in linear infrastructure projects, such as railway construction, where high upfront costs and sequential execution dominate. Under contractual frameworks such as the FIDIC Red Book, where payments are tied to certified physical progress, integrating schedule and cost planning is essential to maintaining financial stability and minimizing contractual disputes. Under contracts such as the FIDIC Red Book, where payments depend on certified physical progress, effective integration of schedule and cost planning is essential [12, 15, 16]. This integration helps maintain financial stability and reduces contractual and financial disputes during the project.

## 3 Case study

### 3.1 Introduction to the case study project

Kosovo is modernizing the Railway Route Corridor X with European loans and grants. This corridor runs from the border with North Macedonia to the border with Serbia, spanning 145 km in Kosovo (figure 1). The project complies with international procurement regulations. It is managed via FIDIC contracts, specifically the 2017 FIDIC Red Book, "Conditions of Contract for Construction of Buildings and Engineering Works Designed by the Employer – General Conditions." This study presents a cash flow analysis using a standard S-curve across three scenarios, integrated with project schedules in Gantt charts to predict cash flow trends. These scenarios are then compared to the initial cash flow projections submitted by contractors for approval by the Contracting Authorities.

The planned completion time for a 34.4 km segment was 18 months. The S-curve cash flow forecast for this segment was created by the Contractor, approved by both the Client and the Engineer, and then became part of the contract. This forecast was a binding document that obligated the Contractor to execute the work and the Client to adhere to the payment schedule. Details of the Kosovo Railway Corridor X, especially Phase II, are shown in figure 1 and in table 1.


**Figure 1** Railway Route Corridor X in Kosovo from the border with North Macedonia to the border with Serbia

**Table 1** Details of the railway sector phase II - Corridor X

| | |
|---|---|
| Railway alignment | 34.4 km (main single line) / 9.1 km (stations) |
| Level crossings | 23 |
| Stations | 5+1 (Fushe Kosove station is included only about its platforms and buildings |
| Stops | 5 |
| Platforms | 17 (i.e. 16 new and 1 rehabilitation of existing at Fushe Kosove) |
| Railway bridges | 17 (i.e. 14 new and 3 rehabilitations of existing) |
| Culverts | 40 box culverts and 23 pipe culverts |

The steps taken before creating the project schedule were as follows:

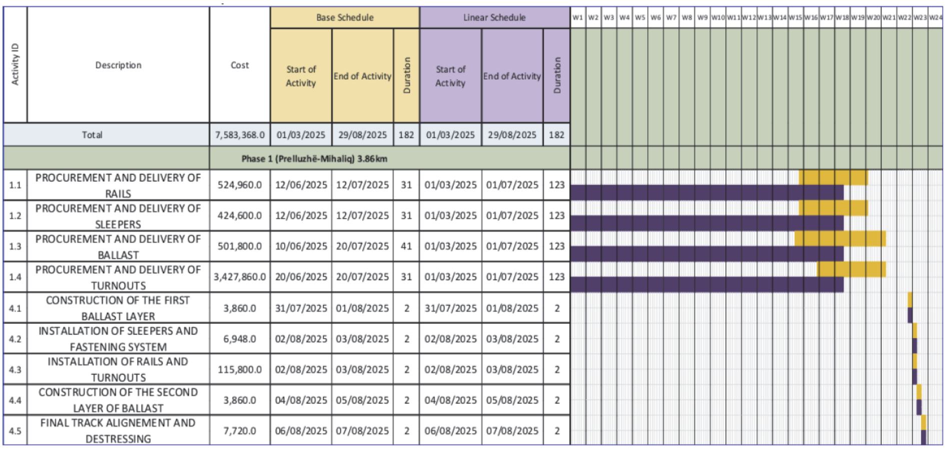
- Developing a work breakdown structure, where the tasks were divided into four categories and then into specific activities:
  - a) procurement works (approximately 45% of the total cost) – procurement of rails, ballast, sleepers and turnouts
  - b) substructure and drainage works (about 22% of the total cost) – earthworks and drainage network construction
  - c) structure works (approximately 17% of the total cost) – construction of culverts, bridges, platforms, and underpasses
  - d) superstructure works (approximately 11% of the total cost) – installation of sleepers, ballast, rails, and turnouts
  - e) contingencies (approximately 5% of the total cost).
- Estimating and assessing the resources required for each activity, including time, materials, labor, and total costs. This was based on standard cost and productivity norms, as well as the team's prior experience [19].
- Analyzing the relationships and constraints between activities, which influence the overall workflow during on-site execution.

## 3.2 Scheduling scenarios

During the planning phase of a construction project, various factors influence the project's outcomes, with some having a greater impact than others [8]. In railway construction, procuring rails, sleepers, ballast, and turnouts is a major cost and a key planning challenge [11, 14, 18]. Therefore, contract negotiations should establish an appropriate advance payment, possibly up to 40%, to support material procurement for such infrastructure projects.

### 3.2.1 Base cash flow schedule vs a non-optimal linear cash flow schedule (scenario 1)

The Base Schedule represents the contractor's proposed plan, aligning procurement with on-site installation needs (see yellow bars in figure 2 below as the base schedule).



| Activity ID | Description | Cost | Base Schedule: Start of Activity | Base Schedule: End of Activity | Base Schedule: Duration | Linear Schedule: Start of Activity | Linear Schedule: End of Activity | Linear Schedule: Duration |
|---|---|---|---|---|---|---|---|---|
| | Total | 7,583,368.0 | 01/03/2025 | 29/08/2025 | 182 | 01/03/2025 | 29/08/2025 | 182 |
| | Phase 1 (Prelluzhë-Mihaliq) 3.86km | | | | | | | |
| 1.1 | PROCUREMENT AND DELIVERY OF RAILS | 524,960.0 | 12/06/2025 | 12/07/2025 | 31 | 01/03/2025 | 01/07/2025 | 123 |
| 1.2 | PROCUREMENT AND DELIVERY OF SLEEPERS | 424,600.0 | 12/06/2025 | 12/07/2025 | 31 | 01/03/2025 | 01/07/2025 | 123 |
| 1.3 | PROCUREMENT AND DELIVERY OF BALLAST | 501,800.0 | 10/06/2025 | 20/07/2025 | 41 | 01/03/2025 | 01/07/2025 | 123 |
| 1.4 | PROCUREMENT AND DELIVERY OF TURNOUTS | 3,427,860.0 | 20/06/2025 | 20/07/2025 | 31 | 01/03/2025 | 01/07/2025 | 123 |
| 4.1 | CONSTRUCTION OF THE FIRST BALLAST LAYER | 3,860.0 | 31/07/2025 | 01/08/2025 | 2 | 31/07/2025 | 01/08/2025 | 2 |
| 4.2 | INSTALLATION OF SLEEPERS AND FASTENING SYSTEM | 6,948.0 | 02/08/2025 | 03/08/2025 | 2 | 02/08/2025 | 03/08/2025 | 2 |
| 4.3 | INSTALLATION OF RAILS AND TURNOUTS | 115,800.0 | 02/08/2025 | 03/08/2025 | 2 | 02/08/2025 | 03/08/2025 | 2 |
| 4.4 | CONSTRUCTION OF THE SECOND LAYER OF BALLAST | 3,860.0 | 04/08/2025 | 05/08/2025 | 2 | 04/08/2025 | 05/08/2025 | 2 |
| 4.5 | FINAL TRACK ALIGNEMENT AND DESTRESSING | 7,720.0 | 06/08/2025 | 07/08/2025 | 2 | 06/08/2025 | 07/08/2025 | 2 |

**Figure 2** Gantt chart base schedule of railway route 10 rehabilitation case study

Procurement of rails, sleepers, and ballast was scheduled to commence in the latter part of the second quarter of the project timeline. This method ensures steady financial flow and aligns cash flow with actual progress (see the black cash flow curve in figure 3 for the Base Schedule).

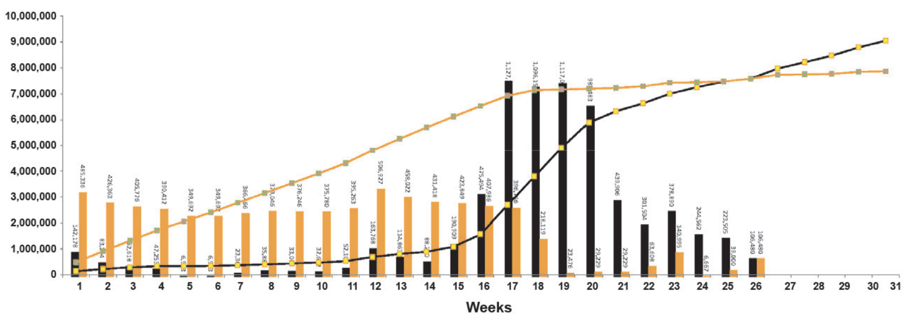



**Figure 3** Cash flow of the base schedule vs. non-optimal schedule

### 3.2.2 Delayed schedule (scenario 2)

One of the most common problems in construction projects is delays. However, how do they affect a project's financial performance? Delays can vary in nature, but fundamentally, they fall into the following two categories (see table 3 for details):

- unforeseeable delays – delays that cannot possibly be predicted in the planning stage
- foreseeable delays – delays that should be noted and considered during the planning stage, within the duration of each activity, as per their possibility of occurring.

These delays are thought to occur during most activities at the start of the project, creating a domino effect that delays subsequent activities (with longer durations) and ultimately prevents the project from being completed on time. The gantt charts and cash flows for the base and delayed schedules are shown in figures 4 and 5, respectively.

| Activity ID | Description | Cost | Base Schedule | | | Delayed Schedule | | |
|---|---|---|---|---|---|---|---|---|
| | | | Start of Activity | End of Activity | Duration | Start of Activity | End of Activity | Duration |
| | Total | 7,583,368.0 | 01/03/2025 | 29/08/2025 | 182 | 01/03/2025 | 13/09/2025 | 189 |
| | | Phase 1 (Prelluzhë-Mihaliq) 3.86km | | | | | | |
| 1.1 | **PROCUREMENT AND DELIVERY OF RAILS** | 524,960.0 | 12/06/2025 | 12/07/2025 | 31 | 12/06/2025 | 11/09/2025 | 85 |
| 1.2 | **PROCUREMENT AND DELIVERY OF SLEEPERS** | 424,600.0 | 12/06/2025 | 12/07/2025 | 31 | 12/06/2025 | 11/09/2025 | 85 |
| 1.3 | PROCUREMENT AND DELIVERY OF BALLAST | 501,800.0 | 02/06/2025 | 12/07/2025 | 41 | 02/06/2025 | 13/09/2025 | 95 |
| 1.4 | PROCUREMENT AND DELIVERY OF TURNOUTS | 3,427,860.0 | 20/06/2025 | 20/07/2025 | 31 | 20/06/2025 | 11/09/2025 | 77 |
| 4.1 | CONSTRUCTION OF THE FIRST BALLAST LAYER | 3,860.0 | 31/07/2025 | 01/08/2025 | 2 | 22/08/2025 | 05/09/2025 | 15 |
| 4.2 | INSTALLATION OF SLEEPERS AND FASTENING SYSTEM | 6,948.0 | 02/08/2025 | 03/08/2025 | 2 | 26/08/2025 | 06/09/2025 | 11 |
| 4.3 | INSTALLATION OF RAILS AND TURNOUTS | 115,800.0 | 02/08/2025 | 03/08/2025 | 2 | 26/08/2025 | 06/09/2025 | 11 |
| 4.4 | CONSTRUCTION OF THE SECOND LAYER OF BALLAST | 3,860.0 | 04/08/2025 | 05/08/2025 | 2 | 28/08/2025 | 06/09/2025 | 9 |
| 4.5 | FINAL TRACK ALIGNEMENT AND DESTRESSING | 7,720.0 | 06/08/2025 | 07/08/2025 | 2 | 30/08/2025 | 06/09/2025 | 7 |

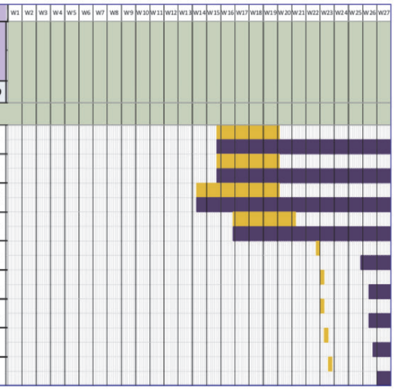



**Figure 4** Gantt chart base schedule (yellow) vs. delayed schedule (purple)

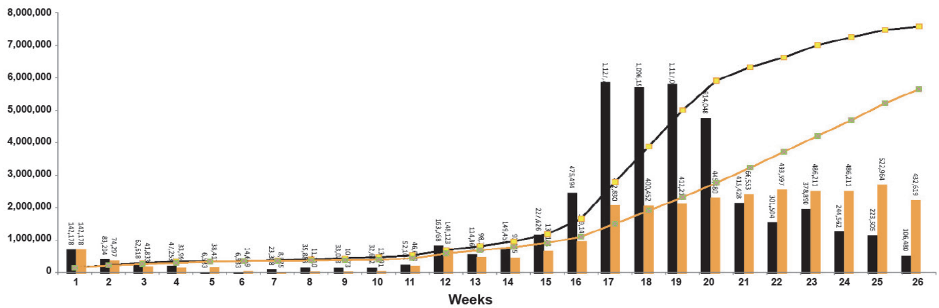
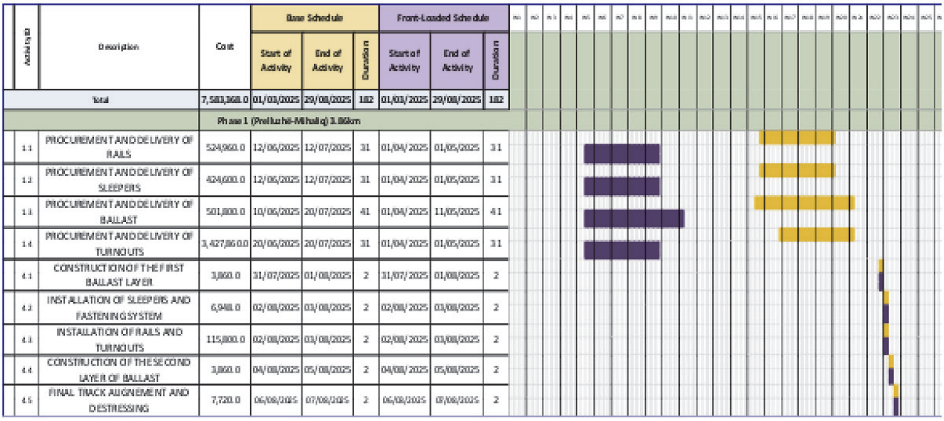



**Figure 5** Cash Flow of the base schedule vs. delayed schedule

### 3.2.3 Front-loaded schedule (scenario 3)

Front-loading is a strategy used by some project managers in which the primary project costs are incurred early. In this case study, it involves the full procurement and storage of key materials such as rails, ballast, sleepers, and turnouts at the project's start, well before they are needed for installation on site. The Gantt charts and cash flows for the front-loaded and base schedules are presented in figures 6 and 7.



| Activity ID | Description | Cost | Base Schedule: Start of Activity | Base Schedule: End of Activity | Base Schedule: Duration | Front-Loaded Schedule: Start of Activity | Front-Loaded Schedule: End of Activity | Front-Loaded Schedule: Duration |
|---|---|---|---|---|---|---|---|---|
| Total | | 7,583,368.0 | 01/03/2025 | 29/08/2025 | 182 | 01/03/2025 | 29/08/2025 | 182 |
| | | Phase 1 (Prelluzhë-Mihaliq) 3.86km | | | | | | |
| 1.1 | PROCUREMENT AND DELIVERY OF RAILS | 524,960.0 | 12/06/2025 | 12/07/2025 | 31 | 01/04/2025 | 01/05/2025 | 31 |
| 1.2 | PROCUREMENT AND DELIVERY OF SLEEPERS | 424,600.0 | 12/06/2025 | 12/07/2025 | 31 | 01/04/2025 | 01/05/2025 | 31 |
| 1.3 | PROCUREMENT AND DELIVERY OF BALLAST | 501,800.0 | 10/06/2025 | 20/07/2025 | 41 | 01/04/2025 | 11/05/2025 | 41 |
| 1.4 | PROCUREMENT AND DELIVERY OF TURNOUTS | 3,427,860.0 | 20/06/2025 | 20/07/2025 | 31 | 01/04/2025 | 01/05/2025 | 31 |
| 4.1 | CONSTRUCTION OF THE FIRST BALLAST LAYER | 3,860.0 | 31/07/2025 | 01/08/2025 | 2 | 31/07/2025 | 01/08/2025 | 2 |
| 4.2 | INSTALLATION OF SLEEPERS AND FASTENING SYSTEM | 6,948.0 | 02/08/2025 | 03/08/2025 | 2 | 02/08/2025 | 03/08/2025 | 2 |
| 4.3 | INSTALLATION OF RAILS AND TURNOUTS | 115,800.0 | 02/08/2025 | 03/08/2025 | 2 | 02/08/2025 | 03/08/2025 | 2 |
| 4.4 | CONSTRUCTION OF THE SECOND LAYER OF BALLAST | 3,860.0 | 04/08/2025 | 05/08/2025 | 2 | 04/08/2025 | 05/08/2025 | 2 |
| 4.5 | FINAL TRACK ALIGNEMENT AND DESTRESSING | 7,720.0 | 06/08/2025 | 07/08/2025 | 2 | 06/08/2025 | 07/08/2025 | 2 |

**Figure 6** Gant chart base (yellow) vs. front-loading schedule (purple)

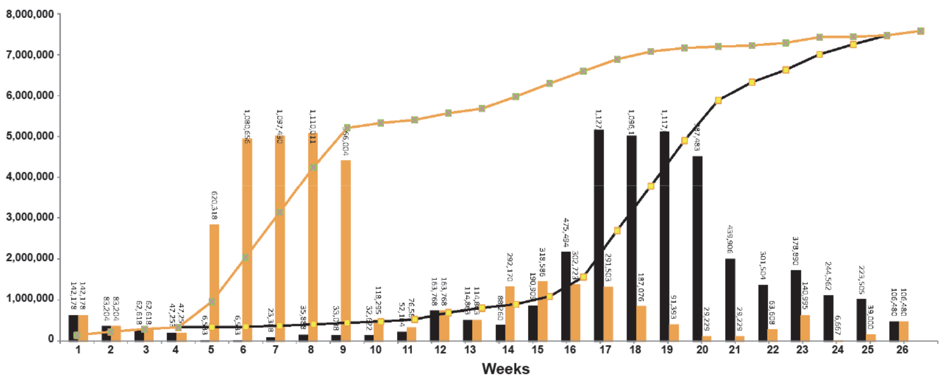



**Figure 7** Cash flow of the base schedule vs. front-loading schedule

# 4 Discussion and implications

These findings have important implications for infrastructure stakeholders and policymakers, particularly given the limited recent research on aligning construction schedules with cash flow management [9]. For public clients and funding institutions, the results emphasize the need to link payment disbursements to verified construction progress to protect public funds and reduce financial and contractual risks. Progress-based payment mechanisms enhance transparency and limit the risk of project discontinuity [13, 17]. For contractors, the study indicates that aggressive strategies such as front-loading may provide short-term liquidity but can compromise long-term project stability. Although early financial relief is achieved, such approaches increase exposure to later financial stress and may adversely affect quality and schedule performance [10].

## 5 Conclusion

This study demonstrates that integrating construction scheduling with cash flow management is critical to the successful delivery of infrastructure projects, particularly railways, which are vulnerable to mismatches arising from sequential construction, specialized materials, and high upfront costs. Misalignment between time and financial planning increases the risks of liquidity issues, delays, and contractual disputes. The case study shows that schedules aligned with actual progress produce stable cash flow patterns, supporting ongoing production and financial stability. In contrast, front-loaded or linear cash flow strategies, while providing short-term liquidity, can distort progress reporting and elevate financial stress and project delays. Delays further ripple through procurement, logistics, and recurring site costs, underscoring the interdependence of schedule and cash flow.
These findings highlight the need to manage scheduling and cash flow as interconnected control mechanisms. For railway projects, advance payments are essential for timely material procurement but must be secured through financial safeguards such as bank guarantees and progress-based certifications. In publicly funded projects, aligning schedules with disbursement plans enhances transparency, reduces financial risk, and promotes resilient infrastructure delivery.

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