ДГКС ASES | E-44
Kongres 2026
Congress 2026

doi: 10.67563/ASESCONF2026039P

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IMPACT OF CHANGING EXECUTION CONDITIONS ON CONSTRUCTION SCHEDULE AND ACCELERATION MEASURES: THE OLD SAVA BRIDGE DISMANTLING CASE STUDY

Summary: Schedule performance is a central aspect of infrastructure project delivery, as changes in execution conditions and additional safety requirements may significantly alter schedule logic and extend the duration of critical activities, with organizational and financial consequences. This paper presents a case study of the dismantling of the Old Sava Bridge in Belgrade, focusing on the schedule impact of protective measures required by the demining authority and on the modification of the main-span dismantling methodology developed to mitigate these effects. The introduction of protective measures in the riverbed zone constituted a new execution constraint that affected the originally planned sequence of works and required modification of the construction methodology. The results show that the proposed measures reduce project duration by approximately 100 days; however, completion remains delayed by about 97 days compared to the baseline programme.

Keywords: schedule impact, acceleration measures, construction schedule, bridge dismantling, execution conditions

UTICAJ PROMENE USLOVA IZVOĐENJA NA PLANIRANI ROK IZGRADNJE I MERE ZA UBRZANJE: STUDIJA SLUČAJA DEMONTAŽE STAROG SAVSKOG MOSTA

Rezime: Vremenske performanse predstavljaju jedan od ključnih aspekata realizacije infrastrukturnih projekata jer promene uslova izvođenja i uvođenje dodatnih bezbednosnih zahteva mogu značajno izmeniti logiku dinamičkog plana i produžiti trajanje kritičnih aktivnosti, uz organizacione i finansijske posledice. U radu je prikazana studija slučaja demontaže Starog savskog mosta u Beogradu, sa fokusom na vremenski uticaj zaštitnih mera zahtevanih od strane nadležnog centra za deminiranje i na izmenu metodologije demontaže glavnog raspona razvijenu radi ublažavanja tih efekata. Uvođenje zaštitnih mera u zoni rečnog korita predstavljalo je novo ograničenje izvođenja koje je uticalo na prvobitno planiranu sekvencu radova i zahtevalo izmenu metodologije izvođenja. Rezultati pokazuju da predložene mere skraćuju trajanje projekta za oko 100 dana, ali završetak projekta ostaje pomeren za oko 97 dana u odnosu na bazni program radova.

Ključne reči: vremenska mitigacija, mere ubrzanja, demontaža mosta, tehnologija izvođenja, neizvesnost uslova izvođenja

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1. INTRODUCTION

The schedule performance of an infrastructure project does not depend only on the initially planned quantities, resources and construction methodology. In complex works, particularly in zones affected by water, limited working space and specific safety regimes, the project is exposed to events that may subsequently change the execution conditions. Such events do not act only as local disruptions of an individual activity; they may modify the assumed method of construction, the sequence of works and the project critical path. Their consequences are typically reflected in schedule disruption, prolongation of critical-path activities, and additional costs resulting from extended execution periods, resource remobilization, and changes in site organization.

The subject of this paper is the dismantling of the Old Sava Bridge in Belgrade, carried out within the project for the construction of a new bridge over the Sava River. In the case analysed, additional protective measures for works in the riverbed zone introduced a new safety and technological constraint for specific activities. Their introduction changed the conditions under which water-based works could be performed, including the organisation of floating equipment, access to work fronts, sequencing of preparatory and main activities and dependencies between temporary works, piles and the dismantling of the main span. As a result, the originally planned sequence could no longer provide an acceptable execution flow without a significant time extension, and it became necessary to modify both the dismantling methodology and the logic of the construction schedule.

The objective of the paper is not to examine contractual liability, but to analyse the mechanism of time mitigation: how uncertainty and new external requirements affect the construction schedule, why a change in methodology becomes necessary, how this change is translated into network logic and what time effect it can produce. The case demonstrates that substantial delay mitigation can be achieved only when technical feasibility, construction methodology and schedule logic are considered as an integrated system.

2. LITERATURE REVIEW

Time management in construction projects uses the Critical Path Method (CPM) as one of the principal tools for defining activity sequences, interdependencies and the activities that determine project completion [1]. In construction management literature, the schedule is not regarded merely as a calendar representation of works, but as a time model of the selected construction methodology, available resources and site organisation [2,3]. Therefore, the quality of a programme depends not only on activity durations, but also on whether the network logic reflects the actual method of execution, temporary works, spatial constraints and required control points.

In complex infrastructure projects, changed execution conditions may have a broader effect than the local extension of a single activity. Literature indicates that such events may alter the feasible work sequence, access to work fronts, the order of temporary works and the project critical path [2,4,5]. This is particularly relevant for works over water, where execution depends on floating equipment, temporary structures, navigation regimes, safety approvals and short operational windows. Under such conditions, a new external requirement may have a systemic schedule effect because it changes the assumptions on which the original programme was based.

Project acceleration is often considered through additional resources, extended working hours or reduced durations of individual activities. In complex works, however, this approach is not always sufficient or technically justified. Where constraints are related to the method of execution, site access, safety or temporary works, the actual acceleration potential more often results from a change in construction methodology, resequencing of activities and a different organisation of work packages [2,3,6]. In this sense, acceleration is not only a productivity issue, but also a question of whether the works can be organised according to an alternative and technically feasible logic.

It is particularly important to distinguish between nominal and technically grounded acceleration. Nominal acceleration can be shown in a programme by reducing durations or overlapping activities, but such a change has limited value if it is not supported by the method statement. Technically grounded acceleration requires that the alternative sequence is feasible in terms of structural behaviour, equipment, temporary works, access, safety, permits and quality control. In bridge dismantling and over-water works, each change in sequence must therefore be assessed together with structural stability, unloading stages, temporary support conditions and the handling of large elements.

The literature review therefore indicates three positions relevant to this paper. First, the construction schedule must be aligned with the actual method of execution. Second, changed external conditions may have a systemic impact on the critical path, particularly in water-based and constrained work zones. Third, effective time mitigation in complex infrastructure projects often requires a change in methodology and resequencing, not only the nominal shortening of activities.

3. CASE STUDY CONTEXT

The Old Sava Bridge was a riveted steel structure with seven spans and a total length of approximately 401.2 m (Figure). The span arrangement was 41.3 + 53.1 + 53.1 + 106.2 + 53.1 + 53.1 + 41.3 m, with the central span formed as a tied-arch system. The main load-bearing steel members were made of St52 steel, while secondary members were made of St37 steel.

This configuration directly influenced the dismantling methodology. The central span, existing hangers, tie member and secondary structure determined the possible zones of temporary support, the sequence of structural unloading, the cutting locations and the method for lowering and transporting dismantled elements. For this reason, the dismantling of the main span could not be considered merely as removal of steelwork, but as a controlled construction operation in which the stability of the structural system had to be maintained until its safe relocation or support on temporary structures.

During project execution, additional protective measures in the riverbed zone were introduced following investigations and instructions issued by the competent demining authority. The reason for their introduction was the risk associated with works in the riverbed, particularly during piling, removal of existing elements, operation of floating equipment and other activities that could disturb material in the riverbed. The measures concerned additional safeguarding of water-based work zones, organisation of water operations, protection of equipment and formation of protective zones before the start of specific activities. As a result, water-based works received a new safety and technological precondition.

The protective measures primarily affected the chain of water-based works preceding the construction of the new bridge elements: riverbed preparation, piling, implementation of protective measures, cofferdam works, pile caps and piers in the C3 and C4 zones. Since these activities are technologically interdependent, the additional safety preconditions did not remain a local intervention. They modified the available sequence of works and transferred the risk to subsequent stages, including temporary works and main-span dismantling.

Under these conditions, the time impact could not be mitigated only by increasing work intensity or shortening individual activities. After the side spans had already been dismantled, the key issue concerned the main span and the dependency of its dismantling on the completion of MACRS measures and the construction of launch beam elements in the river. The original sequence, based on transverse dragging of the main span onto launch beams in the river, no longer provided an acceptable execution flow. Consequently, a methodology for longitudinally moving the main span to the construction plateau was developed, including additional structural strengthening, modified support conditions and a different organisation of floating equipment.

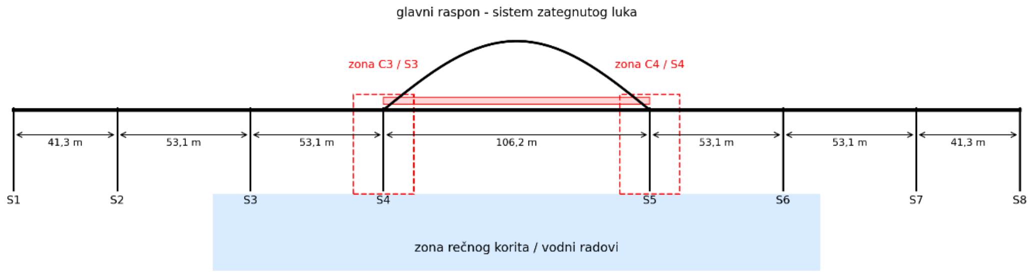

Figure 1: Layout of the Old Sava Bridge and water works zones relevant to the change in dismantling methodology

4. DISMANTLING METHODOLOGY AND TECHNICAL BASIS FOR ACCELERATION

The changed execution conditions described above required the acceleration to be treated not as a simple shift of dates or reduction of activity durations, but as a consequence of changed methodology. For works that depend on structural behaviour, temporary systems and water-based operations, any revised network logic must have a clear technical basis.

In the analysed case, the technical basis for acceleration was the modification of the main-span dismantling methodology. The originally planned methodology envisaged lowering and transporting the main span by barges, followed by transverse dragging onto two launch beams in the river. Supports on the pier footings, lowering of the main span and barge transport were therefore part of the initial concept. However, after dismantling of the side spans, when only the main span remained in the river, the MACRS measures for works on the launch beams in the river had not yet been fully defined. In addition, even after their definition, further time would have been required for implementation of these measures and for the construction of launch beam parts in the river.

For this reason, an alternative methodology was developed in which the main span was moved longitudinally to the construction plateau instead of being transversely dragged onto launch beams in the river. This sequence required the construction of a long shore-side concrete launch beam with a steel cantilever towards the river, as well as additional strengthening of the main span due to changed support positions during dragging. It also required an extended engagement and adaptation of floating equipment. In this sense, the methodological change was not a simple equipment substitution, but a change in the direction, support conditions and organisation of the main dismantling manoeuvre.

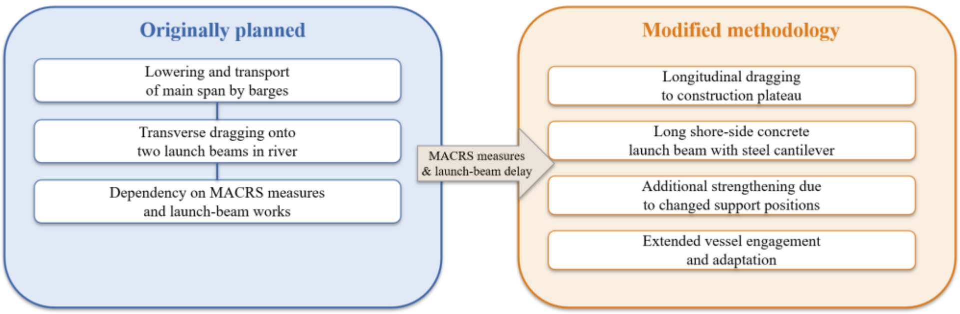

Figure 2: Modification of the main-span dismantling methodology: from transverse dragging onto launch beams in the river to longitudinal dragging onto the construction plateau

The essence of the change was that the main dismantling operation was redirected from transverse dragging over the launch beam system in the river to longitudinal dragging towards the construction plateau. This avoided waiting for the completion of conditions required for works on the launch beams in the river, including definition and implementation of MACRS measures. Although the originally planned transverse dragging was technically and technologically more favourable, the modified methodology enabled a time-admissible execution sequence to be formed (Figure).

The method statement also defines the division of the steel structure into dismantling units (Figure 1: Dismantling units of the steel structure according to the method statement [7]Figure 1). A total of thirteen units were defined, with dimensions and weights coordinated with the lifting capacity of cranes on land and on water, transport limitations and requirements for maintaining structural stability during cutting, lowering and relocation. The side spans were not the subject of the key methodological change, as their dismantling had initially been planned using floating equipment; the change concerned the main arch span [7].

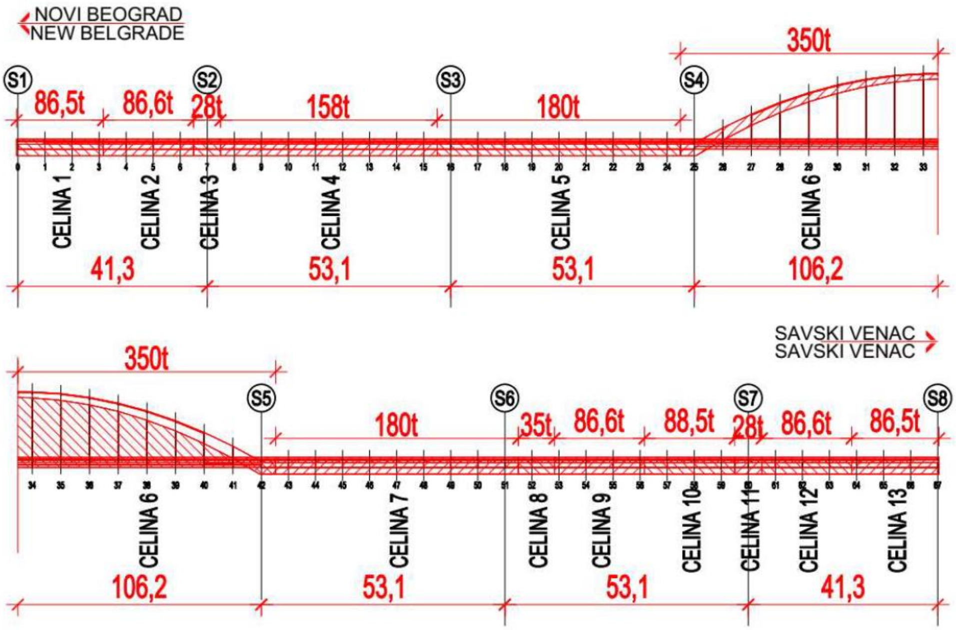

Figure 1: Dismantling units of the steel structure according to the method statement [7]

The conditions for water manoeuvres have particular planning relevance. The method statement defines functional tests of the climbing presses on barges, verification of water level, wind speed limitations, radio communication, barge anchoring, navigation regimes and required navigation closures. For dismantling of the arch part, full navigation closure of 48 hours was foreseen, while a 24-hour closure was foreseen for the approach steel structures. The safe execution of water manoeuvres was also limited to wind speeds up to 40 km/h [7]. This means that the main manoeuvre cannot be treated as a freely movable activity, but as a short operational window requiring completed preparation, approvals, equipment checks and navigation coordination.

The planning significance of the modified methodology is that it provides the technical basis for new network logic. Longitudinal dragging of the main span reduces dependency on the completion of launch beams in the river, additional strengthening enables changed support positions, and the division into dismantling units aligns work phases with equipment capacities (Figure 2).

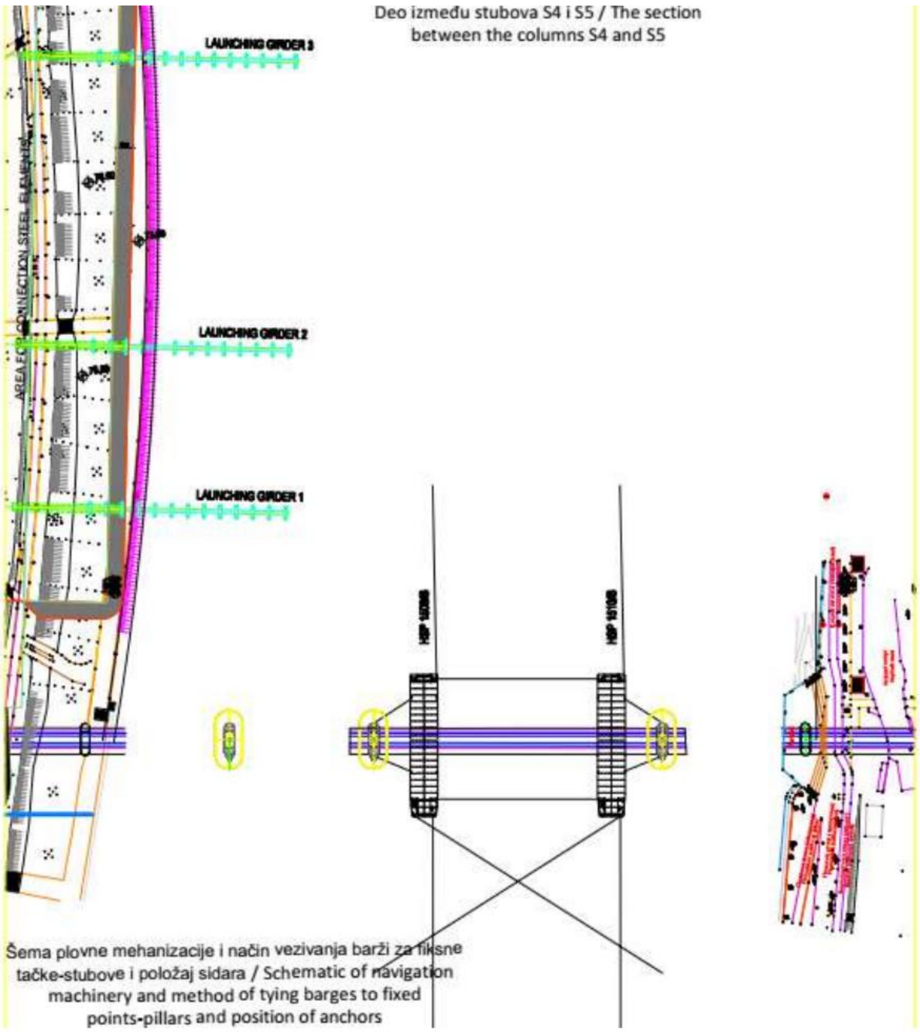

Figure 2: Extract from the method statement: navigation machinery, barge tying arrangement and anchor positions [7]

Based on this technical arrangement (**Error! Not a valid bookmark self-reference.**), a revised schedule can be formed in which acceleration results from methodology modification and resequencing, rather than only from nominal reduction of activity durations. This establishes the link between the technical solution for main-span dismantling and the time effect quantified by comparing the baseline and revised programmes.

Table 1: Technological elements of the methodology and their planning interpretation

Technological element	Planning interpretation
Originally planned transverse dragging onto launch beams in the river	Technically more favourable solution, but time-adverse due to waiting for MACRS measures and construction of launch beam parts in the river.
Longitudinal dragging of the main span to the construction plateau	Reduces the time dependency of main-span dismantling on launch beam works in the river.
Shore-side concrete launch beam with steel cantilever	Provides receiving and guiding support for longitudinal movement of the main span towards the construction plateau.
Additional strengthening of the main span	Enables changed support positions during dragging and control of the structural stress state.
Extended engagement and adaptation of floating equipment	Enables execution of the revised sequence of lowering, positioning and transporting the main span.
Dismantling units and operational windows	Aligns element weights with equipment capacities and requires preparation, approvals and checks to be completed before main manoeuvres.

5. TRANSLATION OF THE METHODOLOGY CHANGE INTO THE CONSTRUCTION SCHEDULE

The technical modification of the main-span dismantling methodology becomes relevant for project time only when it is translated into the construction programme. In this study, the schedule effect is assessed through three programme references: the baseline programme, the programme after the introduction of additional constraints, and the acceleration programme based on the modified main-span dismantling methodology. The key planning issue is therefore not the nominal shortening of activity durations, but the reduction of schedule dependency between the main-span dismantling operation and the completion of launch-beam works in the river.

In the programme after additional constraints, the main-span removal remained dependent on the river-based launch-beam arrangement. The originally planned methodology assumed lowering and transport of the main span by barges, followed by transverse dragging onto two launch beams in the river. After the protective measures were introduced, the launch-beam works in the river became time-critical because they required defined and implemented MACRS measures before they could proceed. This created a significant schedule constraint at the point where the side spans had already been dismantled and the remaining critical operation was the relocation of the main span.

The acceleration programme changes this dependency by adopting the modified main-span dismantling methodology. Instead of transversely dragging the main span onto launch beams in the river, the main span is longitudinally dragged to the construction plateau. This required a long shore-side concrete launch beam with a steel cantilever towards the river, additional strengthening of the main span due to changed support positions, and extended engagement and adaptation of floating equipment. The acceleration is therefore achieved by creating a technically feasible alternative route for the main-span relocation, rather than by simply compressing the duration of the original sequence.

In programme logic, this change replaces a delayed river-work dependency with a different set of predecessors: shore-side temporary works, strengthening of the existing steel structure, preparation of floating equipment, controlled lowering, and longitudinal dragging to the construction plateau. The main planning effect is that the removal of the main span is no longer governed to the same extent by the completion of the river-based launch-beam works. This allows the programme to recover part of the time lost due to the additional protective requirements.

From a construction management perspective, the acceleration should be interpreted as methodology-based schedule mitigation. It is not a purely mathematical overlap introduced in the network and it is not primarily a productivity increase. Its validity depends on whether the revised sequence can be supported by temporary works design, vessel availability, strengthening works, operational windows, navigation arrangements, survey control and safety approvals. Only when these technical preconditions are satisfied can the revised schedule logic be considered feasible and defensible.

The planning interpretation of the methodology modification is summarised in Table 2. The table shows how the original constrained sequence and the acceleration programme differ in terms of the main-span movement, dependency on river works, temporary works and overall planning effect.

Table 2: Planning logic before and after acceleration

Planning aspect	Programme after additional constraints	Acceleration programme based on the modified methodology
Main-span movement	Lowering and transport by barges, followed by transverse dragging onto two launch beams in the river.	Longitudinal dragging of the main span to the construction plateau.
Main schedule dependency	Completion of MACRS measures and launch-beam works in the river.	Reduced dependency on the delayed river-based launch-beam works.
Temporary works response	Reliance on the initially planned launch-beam arrangement in the river.	Long shore-side concrete launch beam with steel cantilever towards the river.
Structural and equipment requirements	Original support and dragging concept retained, subject to completion of river works.	Additional strengthening due to changed support positions and adapted use of floating equipment.
Planning effect	Later completion due to the constrained river-work sequence.	Earlier main-span relocation and partial recovery of the time impact.
Acceleration mechanism	No effective bypass of the delayed launch-beam dependency.	Methodology modification and resequencing of the main-span dismantling operation.

6. QUANTIFICATION OF THE SCHEDULE EFFECT

The time effect can be assessed by comparing three planned completion dates. The baseline programme planned project completion on 01.09.2027. After the introduction of additional constraints, the revised programme indicated completion on 16.03.2028, representing a shift of 197 calendar days compared with the baseline programme. The acceleration programme based on the modified main-span dismantling methodology indicated completion on 07.12.2027. The difference between the constrained programme and the acceleration programme is 100 calendar days. The accelerated programme therefore recovers part of the time impact, but it remains 97 calendar days later than the baseline completion (Figure 3), (Table 3).

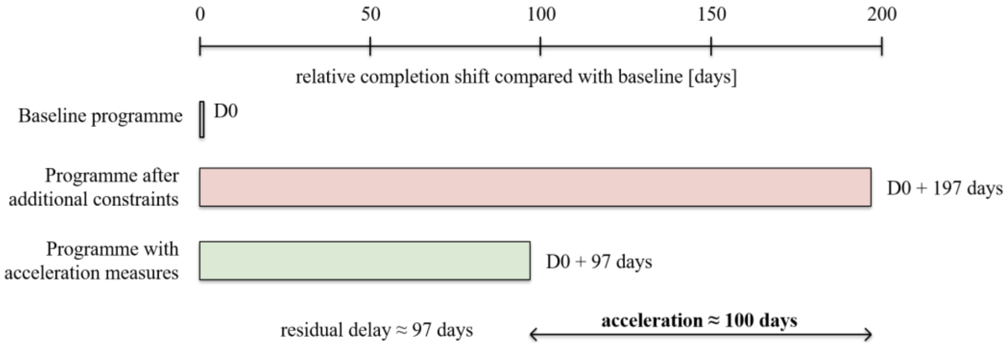

Figure 3: Relative effect of delay, acceleration and residual delay

Table 3: Quantification of the time effect of acceleration measures

Indicator	Value	Interpretation
Baseline project completion	**01.09.2027**	Reference completion date according to the baseline programme.
Completion of the programme after additional constraints	**16.03.2028**	Completion after introduction of additional constraints, without acceleration effect.
Total shift compared with the baseline programme	**197 days**	Difference between 01.09.2027 and 16.03.2028.
Completion of the acceleration programme	**07.12.2027**	Completion after methodology modification and resequencing.
Time saving achieved by acceleration	**100 days**	Difference between 16.03.2028 and 07.12.2027.
Residual delay compared with the baseline programme	**97 days**	Difference between 01.09.2027 and 07.12.2027.
Dominant mechanism of saving	Methodology modification and resequencing	The saving results from changed planning logic rather than a simple reduction of activity durations.

The quantification confirms that the proposed acceleration has the character of time mitigation: the time shift is reduced from 197 to 97 days, but it is not completely eliminated.

7. DISCUSSION AND CONCLUSION

The presented case study shows that external events and subsequently introduced requirements in infrastructure projects may have a broader impact than a local stoppage of a single activity. When a new requirement concerns safety of works in the riverbed zone, the consequences are transferred to technological assumptions, organisation of temporary works, activity sequencing and critical path logic. In such circumstances, project acceleration cannot be reliably based only on extended working hours, additional resources or nominal reduction of activity durations; it requires a change in the method of execution.

In the analysed case, the technical solution based on longitudinal dragging of the main span to the construction plateau, construction of a shore-side launch beam with steel cantilever, additional strengthening of the main span and adjusted use of floating equipment reduced the time dependency on completion of launch beams in the river and the MACRS measures preceding those works. From the planning perspective, the key effect was the ability to change the work sequence and organise part of the previously serial activities as a partially parallel flow.

The comparison between the constrained programme and the acceleration programme shows that the largest time effect is achieved by reducing the dependency of main-span dismantling on completion of the launch-beam works in the river. The modified methodology enabled the main span to be moved longitudinally to the construction plateau, instead of following the originally planned transverse dragging sequence onto launch beams in the river. Quantification shows that this methodology modification produced a significant but partial effect. The baseline project completion was 01.09.2027, the programme after additional constraints indicated completion on 16.03.2028, and the acceleration programme indicated completion on 07.12.2027. This represents a time saving of 100 days compared with the constrained programme, while the project remains approximately 97 days delayed relative to the baseline programme.

A key conclusion is that any schedule modification must be technically justified. The acceleration programme can be realistic only if temporary systems, floating equipment, working space in the riverbed, required approvals, navigation coordination and control points for safe execution are in place. Otherwise, resequencing remains only a planning change in the network without sufficiently demonstrated site feasibility. The principal contribution of the case is the connection between three levels: changed execution conditions, modified dismantling methodology and measurable schedule effect. The study shows that, in complex infrastructure projects, the time impact of uncertainty can be mitigated only if construction methodology and schedule logic are developed together. Such an approach allows acceleration measures to be not only represented in the programme, but also technically feasible and professionally defensible.

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