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RESEARCH ARTICLE

Co-management of risks and complexities to improve schedule management in engineering projects

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Abstract

Schedules play a pivotal role in engineering projects and are used primarily to manage time, but also costs, labor, and other resources. Managing schedules can be challenging due to the frequent impact of risks and uncertainties on planned activities, resulting in deviations from expected progress. In addition to risks, today's large-scale engineering projects also face complexities. Therefore, it is important to identify complexities, incorporate them into schedule risk analysis and manage them flexibly, along with risks, in accordance with the dynamics of such projects. Traditional approaches of project management, however, are relatively rigid and plan-driven, and lack sufficient managerial flexibility to cope with the challenges and dynamics of complex projects. In this regard, the aim of this study is to propose a flexible and integrated procedure for co-managing risks and complexities that affect project schedules. The procedure was developed using complexity assessment and schedule risk analysis methods, along with a set of flexibility-enabling principles of project management identified through relevant literature. This way, it is aimed to bridge between theory and practice and to extend the territory of traditional project risk management. The proposed procedure was then implemented on a project, both retrospectively and hypothetically, using actual project information. The main reasons identified for the delays in the project included insufficient interaction with stakeholders, lack of involvement in processes, failure to adopt perception-based management, and the lack of a shared mental model regarding perceived complexities. It was concluded that, in response to schedule risks, embracing complexity to exploit opportunities rather than attempting to reduce complexity (which is not easy to achieve in general) would be an appropriate strategy to pursue to establish fit-for-purpose management and achieve enhanced risk responses. Consequently, the co-management of risks and complexities was suggested to improve schedule management in large-scale engineering projects.

1. Introduction

Engineering projects are executed under challenging conditions involving a variety of interconnected activities. To effectively manage such complex working environments and ensure timely delivery of projects within budget, scope, and compliance with contracts and relevant

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legislation, it is almost inevitable to apply project management principles and processes. These processes include, among others, "project schedule management" and "project risk management", as proposed by the PMBOK® Guide 6th Edition [1]. In case of large engineering projects such as railway and highway infrastructure projects, which can be considered complex by nature, the working environment becomes very complicated, and the effect of uncertainty increases [2]. In these projects, the need for concurrent management of risks and complexities evolves, given the need for a paradigm shift because of increasing complexity and uncertainty of construction projects. Managing schedule risks, which are specific to schedules among the larger group of project risks, requires performing risk identification, risk analysis, and risk response (mitigation) tasks, with a particular focus on schedules.

Schedules play a pivotal role in engineering projects and are used primarily to manage time, but also costs, labor, and other resources. However, managing schedules is challenging as risks frequently affect planned activities and lead to deviations from expected progress. This necessitates applying schedule risk analysis and determining schedule-related risk response actions in advance. Moreover, as above-mentioned, not only risks but also complexities stand out in today's large engineering projects. Therefore, assessing complexities and incorporating them into schedule-focused risk management gain importance for successfully completing such projects.

In this context, the aim of this study is to propose a flexible and integrated procedure for co-managing risks and complexities that influence project schedules. The procedure is built upon previously developed complexity assessment and schedule risk analysis methods, utilizing a set of flexibility-enabling principles or features of project management identified through literature review.

The following sections firstly include an examination of the relevant literature. Secondly, the research approach followed and the conceptual framework used are introduced. Thirdly, the proposed procedure is described. Subsequently, the procedure is applied retrospectively and hypothetically to a project using actual project information. Afterwards, the results of this application are discussed. Finally, conclusions are presented, and recommendations for future studies are introduced, including the strengths, advantages, and limitations of the procedure, its implications for theory and practice, and how this approach can help organizations to make better decisions.

2. Literature Review

Many studies confirm the interrelationships among risks and the links between complexities and risks. For instance, Ackermann et al. [3] view project risks as a network of interrelated possible events, emphasizing that a holistic view integrating complexity and risk assessment is necessary to obtain realistic results. A study by Senescu et al. [4] measured data from 69 test projects that supported the assumption that risk exposure can increase when faced with complexities. San-Cristóbal et al. [5] highlighted that as today's projects are becoming more complex, concerns are arising regarding project complexity as a concept in relation to the implementation of traditional tools. The same study further argues for the necessity of extending the risk to complexity from conceptual and practical perspectives. Vidal et al. [6] demonstrate a way of dealing with risks from a complexity-based perspective by presenting a framework that links the uncertainty and risk to complexity. Vidal and Marle [7] view project complexity as a source of project risks, either directly or indirectly, and recommend complexity assessment modeling as an aid for project risk management. Erol et al. [8] introduced complexity-based thinking into the risk management of mega construction projects, based on the idea that complexity often acts as a source of risk events along with uncertainty. In the study of Erol et al. [8], the links between complexity and risk in megaconstruction projects were investigated by taking uncertainty and management strategies into account and an integrated risk assessment process for mega construction projects was proposed. Qazi et al. [9] emphasized that project complexity is a leading factor for the failure of large projects in terms of cost and time overrun and proposed a process that helps to capture the interdependence between project complexity, risks arising from complexity and project objectives. Moussa et al. [10] disclosed that infrastructure projects are often characterized by inherent complexities that lead to poor performance and proposed an approach to enhance the performance of infrastructure projects based on risks, their interactions and interdependence-induced complexities.

Following the definition provided by Hillson and Simon [11], uncertainties that influence the goals of a project are considered project risks. On the other hand, the definition of complexity has been made as "the state of having many different parts connected or related to each other in a complicated way" and the definition of complex has been stated as "the situation of having many different parts, and is therefore often being difficult to understand" [12]. However, no consensus seems to exist regarding the definition of complexity among researchers [6, 13–16]. For instance, while Baccarini [13] defines complexity as the situation of having many and various interrelated parts, which can be explained based on their degree of differentiation and interdependency, Vidal and Marle [7] propose that complexity is a characteristic of a project that transforms it into a difficult form to comprehend, predict, and control its complete behavior, even with complete and reasonable information provided about the project. Furthermore, the drivers of complexity were presumed in their study to be factors related to the project's size, variety, interdependence, and context [7].

Investigations frequently highlight the low success rates worldwide regarding the completion of projects within planned time and cost, as well as the shortcomings in terms of scope and quality [17]. One of the reasons for failure in projects in general is the increasing complexity [2, 7, 13, 17–19] and its underestimation [15]. In this regard, understanding and addressing the effects of complexities will help achieve success in complex construction projects [20–24] and other engineering projects such as aerospace, design, manufacturing, oil and gas, and information technologies [25]. Furthermore, in the literature, there is a widespread opinion that the complexity level in projects is increasing, leading to difficulties in their management [2, 7, 13, 18]. The literature emphasizing the importance of complexity in projects also sparks a discussion on the inadequacy of traditional project management methods and tools [26]. As projects become more uncertain and complex, traditional project management becomes insufficient in providing the necessary tools to address these challenges adequately [13, 27]. The primary aim of traditional project management is to achieve predetermined goals [28], often defined based on budget, time, and performance [29]. It is generally assumed that it would be possible to define the goals at the beginning of a project [30]. However, various complexities and uncertainties reduce the expected effectiveness of front-end planning [31]. Based on this, recent research aims to develop new methods to address both complexity and uncertainty, thereby managing risk [32] and improving project performance [33]. As a solution, new approaches to increase flexibility in project management are being suggested [29, 30, 34].

This study aims to address this issue from the perspective of schedule risk management to improve schedule management. Previous studies have investigated managing schedule risks from various dimensions. However, the concepts of flexibility and complexity, as well as the integration of schedule risk management with schedule management, remain a research gap in this field. Table 1 includes previous relevant studies on these points and compares them with the current study. This literature review reveals that no studies have addressed these three issues simultaneously. Therefore, the current study aims to fill this gap.

3. Research Approach and Conceptual Framework

The research approach followed in this study is depicted in Fig. 1. In the preceding sections, the research problem, aim, and the literature review were introduced.

Table 1. Previous studies on schedule risk management and a comparison with current study

Reference	Topic	Consideration of Flexibility	Consideration of Complexity	Integration with Schedule Management
[35]	Schedule risk analysis of power transmission and transformation projects	No	Yes	No
[36]	Schedule risk management of information technology outsourcing projects	No	No	Yes
[37]	Risk management for schedule of aerospace engineering projects	No	Yes	No
[38]	Risk management of construction schedules with PERT and Monte Carlo Simulation	No	No	No
[39]	Schedule risk management of railway station projects	No	Yes	No
[40]	Incorporation of activity sensitivity measures into buffer management to manage project schedule risks	No	Yes	Yes
[41]	Schedule risk management for power grid engineering projects' sustainable development	No	Yes	Yes
[42]	Schedule risk management for concrete works	No	Yes	No
[43]	Project schedule risk management through building information modelling	No	Yes	Yes
[44]	Schedule risk management at early project stage	No	Yes	No
Current Study	Co-management of risks and complexities in integration with schedule management	Yes	Yes	Yes

In this section, following the research approach illustrated in Fig. 1, Fig. 2 presents the conceptual framework upon which the approach proposed in this study is built.

The proposed approach requires the use of a number of previously developed methods: Critical Path Method (CPM) Scheduling [1, 45–48], Correlated Schedule Risk Analysis Model (CSRAM) [49, 50], schedule and risk management processes of the PMBOK 6 [1] along with "complexity, flexibility, holistic system thinking and tailoring project delivery" principles promoted by the PMBOK 7 [34], Technical, Organizational and External (TOE) Complexity Assessment Framework [15, 51], Detail-Dynamic Project Management Model [2], Perception-Based Management [52], and Fit-for-Purpose Management [45, 53-55]. Detailed information about these methods can be found in the references cited. Furthermore, brief explanations and the reasons for their use in this study are provided in the 'Appendix A'.

Based on the conceptual framework depicted in Fig. 2, the processes of 'dealing with project complexity' (utilizing the TOE Framework, Perception-Based Management, Detail-Dynamic Complexity Management Model, and Fit-for-Purpose Management), 'project schedule management' (based on CPM), and 'schedule risk management' (as a sub-process of project risk management) were integrated, considering the flexibility requirements of project management.

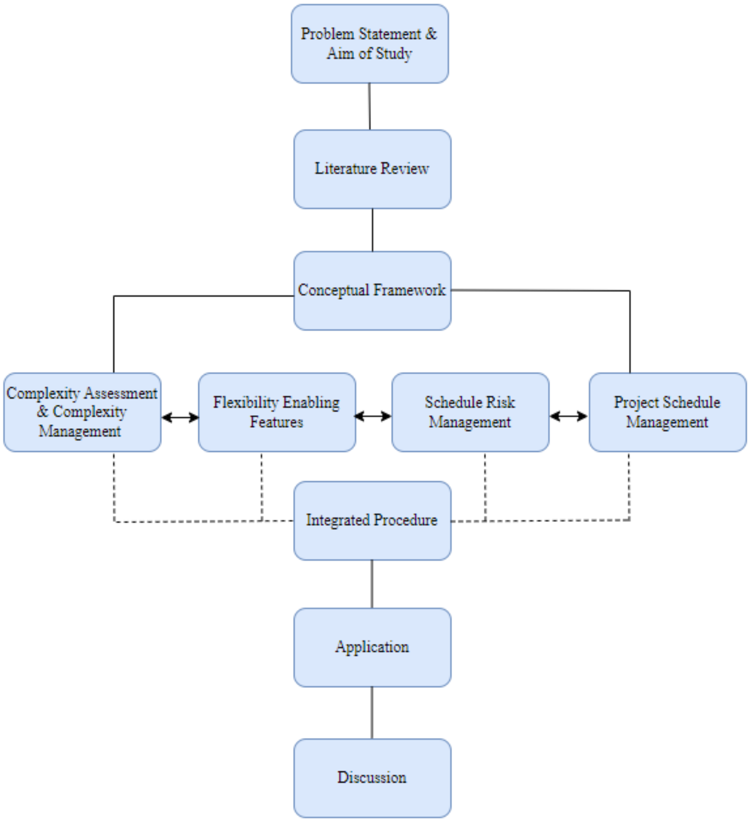

Fig. 1. Research approach of the study

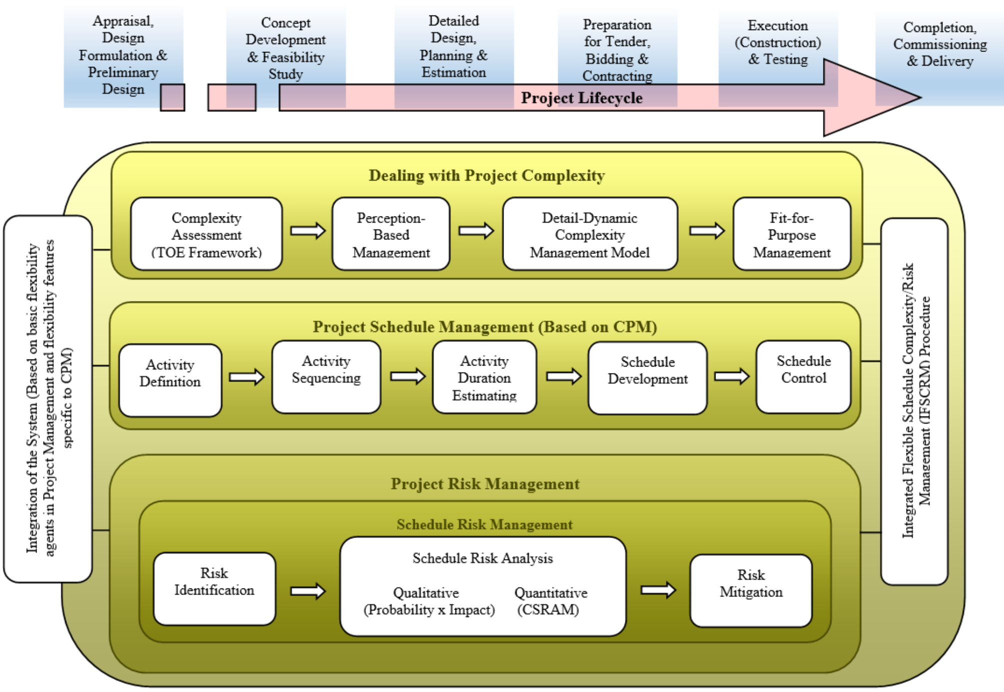

Fig. 2. Conceptual framework of the proposed approach

This integration led to the development of a new procedure called the 'Integrated Flexible Schedule Complexity/Risk Management (IFSCRM) Procedure', which will be referred to simply as the 'Integrated Procedure' throughout the paper. Details about this procedure are explained in the following section.

4. Integrated Procedure

The Integrated Procedure was developed through the utilization of a set of flexibility-enabling features (determined based on basic flexibility principles pertaining to project management and flexibility features specific to CPM) considered to be primarily effective in providing managerial flexibility. Ten different flexibility-enabling features explained below were determined through a literature review carried out using the Project Management Body of Knowledge (PMBOK) Guides [1, 34], the studies of Jalali-Sohi et al. [56–59], and the studies of Ökmen et al. [48, 60]. The traditional plan-oriented approach, which has been the dominant method in project management, has recently been evolving towards a more change-oriented and flexible form. This evolution is driven by the necessity to adapt to project dynamics, complexities, and uncertainties. Alternatively, these two main perspectives can be balanced and tailored through a hybrid approach, as applied in this study, that considers the specific needs and conditions of projects, rather than applying a purely flexible approach such as agile project management methodology [56, 61].

Flexibility-Enabling Feature – 1 (Stakeholder Engagement): Having the ability to engage relevant internal and external stakeholders at all levels is crucial for harmonizing different perceptions and experiences within processes. This is essential for implementing 'Perception-Based Management' and establishing a 'shared mental model' based on the subjective nature of complexity.

Flexibility-Enabling Feature – 2 (Repetitiveness through Iterations): Ensuring repetitive applicability through successive iterations at each milestone, as determined by the baseline and target Critical Path Method (CPM) schedules, is crucial for maintaining the necessary dynamic and adaptable attributes throughout the project execution.

Flexibility-Enabling Feature – 3 (Incorporation of Complexities and Allowance of Data Flow): The ability to integrate the complexity assessment process into the risk management process, particularly concerning scheduling, involves engaging relevant project schedule management processes. This integration aims to directly or indirectly identify complexities that influence the schedule, determine complexity management and risk response strategies simultaneously, and facilitate the flow of data to and from relevant project schedule management processes.

Flexibility-Enabling Feature – 4 (Integrability of Different Frameworks for Complexity and Risk Mitigation): This feature focuses on the applicability of 'Fit-for-Purpose Management' and the 'Detail-Dynamic Project Management Model' to determine complexity management (internal, control, interactive, or dynamic) and risk response actions (reduction, retention, transfer, or avoidance). It also involves utilizing the project complexity footprint identified by the TOE Complexity Assessment Framework, which is based on the experiences and perceptions of the involved stakeholders.

Flexibility-Enabling Feature – 5 (Openness to Improvement and Adaptation): Openness to improvement and adaptation to potential changes through successive iterations during project execution.

Flexibility-Enabling Feature – 6 (Incremental Convergence): Having monitoring, controlling, feedback, and updating capabilities to incrementally converge towards a compatible level of complexity/risk awareness and adopt the most appropriate complexity management and risk response strategies.

Flexibility-Enabling Feature – 7 (Utilization of Managerial Flexibilities in CPM): Ability to benefit from the managerial flexibilities inherent in CPM [48] and expand these flexibilities under uncertainty through Monte Carlo Simulation (MCS) by using CSRAM [60].

Flexibility-Enabling Feature – 8 (Openness to Customization): This feature highlights the readiness for customization based on the unique features and evolving requirements of projects. It involves utilizing various approaches, including complexity assessment methods, risk identification techniques, schedule risk analysis methods, and flexible project management methodologies.

Flexibility-Enabling Feature – 9 (Adaptability across Project Phases): This feature ensures suitability for use throughout various phases of a project's lifecycle by allowing customized modifications whenever necessary, utilizing different flexible project management approaches.

Flexibility-Enabling Feature – 10 (Integrability with Schedule Management Models): Integrability with a schedule management model having similar flexible features.

The process flowchart of the Integrated Procedure is depicted in Fig. 3. The functions and underlying logic of the tasks constituting the procedure's processes are explained step by step below, based on this flowchart, highlighting the flexibility features included in each step. Furthermore, Table 2 presents the process steps of the procedure along with the flexibility features provided within these steps.

Step – 1 (Complexity/Risk Management Planning): The procedure commences with the 'Complexity/Risk Management Planning' process. During this task, details such as staffing, organizing, assignment of responsibilities, utilization of resources, frequency of meetings, and selection of tools and methods are determined and incorporated into a plan. Given that the 'Complexity/Risk Management Planning' process should align with the 'Schedule Management Planning' process outlined in Project Schedule Management [1], data flow is facilitated from the 'Schedule Management Planning' process to the 'Complexity/Risk Management Planning' process. Synchronizing these two analogous processes from distinct but interconnected project management "knowledge areas" – namely, project risk management and project schedule management – would establish essential communication channels among the respective teams and streamline the flow of necessary scheduling-related data. This approach ensures that all stakeholders involved in these processes participate through meetings, brainstorming sessions, and the establishment of effective communication channels. Consequently, 'Flexibility Feature – 1 (Stakeholder Engagement)' is provided. Moreover, establishing an interface between project schedule management and project risk management in this manner also supports 'Flexibility Feature – 10 (Integrability with Schedule Management Models)'. This interface can subsequently be leveraged during the development of a flexible schedule management process.

Step – 2 (Risk Identification and Classification): Next, the procedure progresses to the 'Risk Identification and Classification' process. This phase involves the application of widely recognized techniques such as risk checklists, brainstorming meetings, and risk breakdown structuring. This characteristic aligns with 'Flexibility Feature – 8 (Openness to Customization)'. The process is supported by data from the 'Schedule Development' process in Project Schedule Management, along with the involvement of relevant stakeholders. This aspect ensures the provision of 'Flexibility Feature – 1 (Stakeholder Engagement)'. Furthermore, establishing such an interface aligns with 'Flexibility Feature – 10 (Integrability with Schedule Management Models)', which can later be leveraged in the development of a flexible schedule management system.

Step – 3 (Complexity assessment based on TOE Framework, Refinement of complexities, Refinement of complexity-induced risks): The procedure proceeds with the 'Complexity Assessment Based on TOE Framework' process. This stage considers the subjective nature of complexity and employs Perception-Based Management.

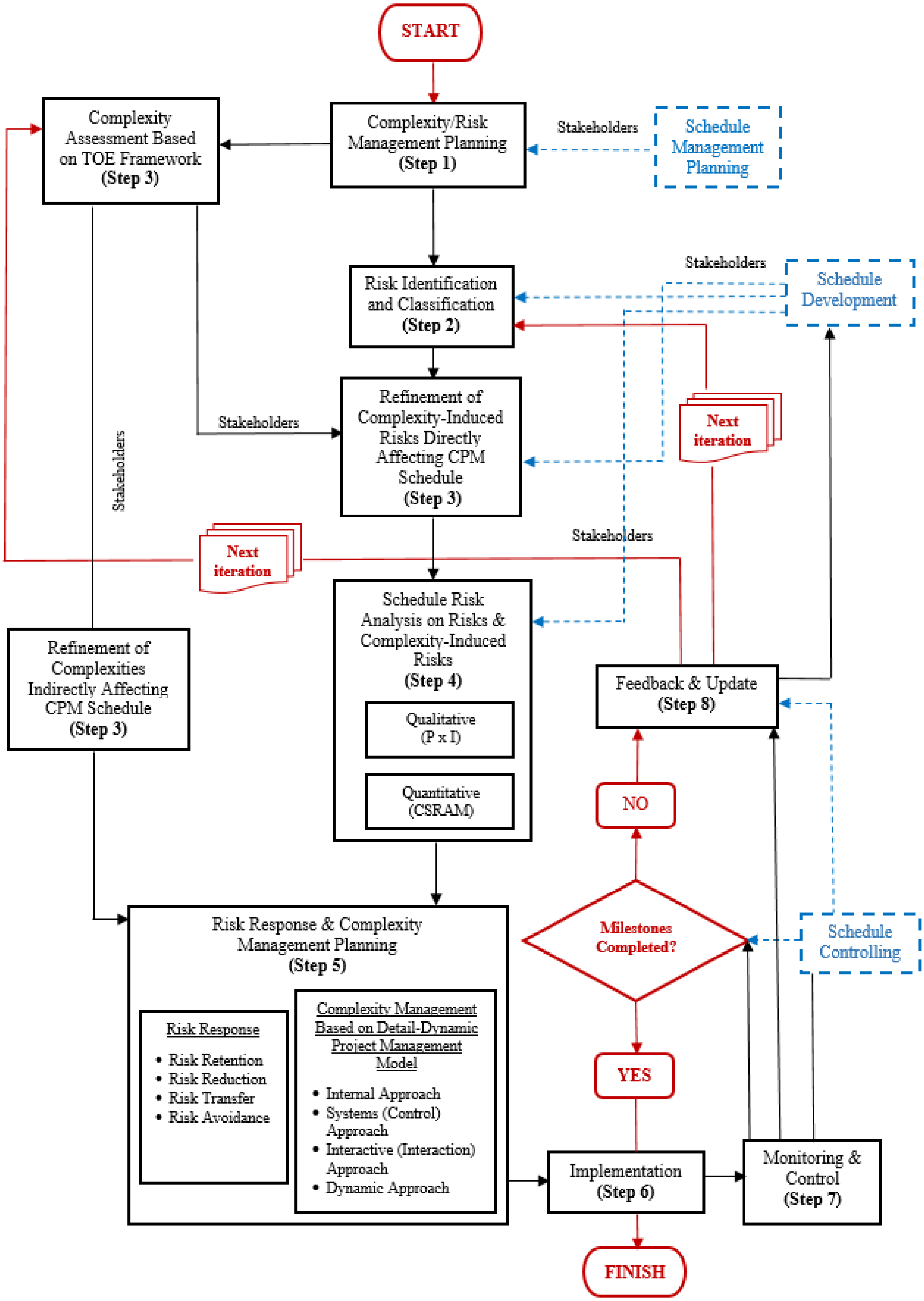

Fig. 3. The process flowchart of the Integrated Procedure

Table 2. The steps of the Integrated Procedure and the flexibility features provided

Step No.	Step Title(s)	Provided Flexibility-Enabling Feature No(s)	Flexibility-Enabling Feature Title(s)
1	Complexity/Risk Management Planning	1	Stakeholder Engagement
		10	Integrability with Schedule Management Models
2	Risk Identification and Classification	1	Stakeholder Engagement
		8	Openness to Customization
		10	Integrability with Schedule Management Models
3	Complexity Assessment Based on TOE Framework	1	Stakeholder Engagement
	Refinement of Complexities	3	Incorporation of Complexities and Allowance of Data Flow
	Refinement of Complexity-Induced Risks	8	Openness to Customization
4	Schedule Risk Analysis on Risks & Complexity-Induced Risks	7	Utilization of Managerial Flexibilities in CPM
		10	Integrability with Schedule Management Models
5	Risk Response & Complexity Management Planning	3	Incorporation of Complexities and Allowance of Data Flow
		4	Integrability with Different Frameworks for Complexity and Risk Mitigation
6	Implementation	2	Repetitiveness through Iterations
		5	Openness to Improvement and Adaptation
7	Monitoring & Control	2	Repetitiveness through Iterations
		5	Openness to Improvement and Adaptation
		6	Incremental Convergence
		10	Integrability with Schedule Management Models
8	Feedback & Update	5	Openness to Improvement and Adaptation
		6	Incremental Convergence
		9	Adaptability across Project Phases
		10	Integrability with Schedule Management Models

Through this process, along with the 'Refinement of Complexities' and 'Refinement of Complexity-Induced Risks' processes, various complexities affecting the project at large, those indirectly influencing the CPM schedule, and those directly impacting the CPM schedule (referred to as 'complexity-induced risks') are identified and categorized. It is crucial to involve stakeholders from different organizational positions related to the project and schedule in this multi-stage complexity assessment process. This approach ensures the provision of both 'Flexibility Feature – 1 (Stakeholder Engagement)' and 'Flexibility Feature – 3 (Incorporation of Complexities and Allowance of Data Flow)'. However, it is essential to establish necessary conditions beforehand to ensure a comprehensive assessment of project complexities and the development of a shared mental model through the application of Perception-Based Management. Additionally, the 'Refinement of Complexity-Induced Risks Directly Affecting the CPM Schedule' process is supported by data transferred from the 'Schedule Development' process of project schedule management and the ‘Risk Identification and Classification’ process, as depicted in Fig. 3. Various methods and techniques such as cause-effect analysis, influence diagramming methods, risk breakdown structures, and risk registers can be employed to refine the complexity-induced risks and complexities indirectly influencing the CPM schedule, as suggested in the study by Andringa et al. [62]. Consequently, ‘Flexibility Feature – 8 (Openness to Customization)’ will be provided.

Step – 4 (Schedule Risk Analysis on Risks & Complexity-Induced Risks): Up to this stage, the complexities affecting both the project and the schedule, whether directly or indirectly, have been explored. In addition, project risks have been identified and classified, and the CPM schedule has been developed. Now, the focus shifts to analyzing the risks identified and the complexity-induced risks affecting the CPM schedule, designated as ‘Schedule Risk Analysis on Risks & Complexity-Induced Risks’ in Fig. 3. This process is supported by data from the ‘Schedule Development’ process in project schedule management, involving relevant stakeholders. This interface aligns with ‘Flexibility Feature – 10 (Integrability with Schedule Management Models)’. The ‘Schedule Risk Analysis’ process unfolds in two steps: qualitative risk analysis based on Probability (P) x Impact (I) scoring and quantitative risk analysis based on the CSRAM. Through ‘P x I scoring’, the risks are prioritized and the most effective critical risks are identified out of the broader risk set. These critical risks along with complexity-induced risks are then transferred to quantitative risk analysis stage and analyzed with CSRAM. The application of the ‘Schedule Risk Analysis’ process this way in this step provides the ‘Flexibility Feature – 7 (Utilization of Managerial Flexibilities in CPM)’.

Step – 5 (Risk Response & Complexity Management Planning): The subsequent process is ‘Risk Response & Complexity Management Planning’. In this phase, in addition to standard risk mitigation actions, complexity management strategies proposed by the Detail-Dynamic Project Management Model are employed, as illustrated in Fig. 3 and in alignment with Fit-for-Purpose Management. This approach is consistent with ‘Flexibility Feature – 4 (Integrability of Different Frameworks for Complexity and Risk Mitigation)’. During this process, the outcomes of the ‘Schedule Risk Analysis’ and ‘Refinement of Complexities’ processes, along with other relevant data obtained thus far, are utilized. This ensures the provision of ‘Flexibility Feature – 3 (Incorporation of Complexities and Allowance of Data Flow)’.

Step – 6 (Implementation): After making decisions in the previous process, they can be implemented through the ‘Implementation’ process depicted in Fig. 3. The implementation of the procedure concludes once all project milestones are achieved. However, if milestones are incomplete, iterations continue after conducting the ‘Feedback & Update’ process for the specific milestone. This approach aligns with ‘Flexibility Feature – 2 (Repetitiveness through Iterations)’ and ‘Flexibility Feature – 5 (Openness to Improvement and Adaptation)’.

Step – 7 (Monitoring & Control): Following implementation, the process is monitored and controlled through the ‘Monitoring & Control’ process, aligning with ‘Flexibility Feature – 6 (Incremental Convergence)’. Since the determined risk responses are applied to the CPM schedule, ‘Monitoring & Control’ runs parallel to the ‘Schedule Controlling’ process in project schedule management, as shown in Fig. 3. This interface is consistent with ‘Flexibility Feature – 10 (Integrability with Schedule Management Models)’. These parallel interfaced processes end up at the decision point labeled ‘Milestones Completed?’. The primary aim is to ensure repetitive implementation of the Integrated Procedure, beginning with the re-implementation of ‘Complexity Assessment Based on TOE Framework’ and ‘Risk Identification and Classification’ processes until all CPM schedule milestones are achieved. This repetitive nature of the procedure aims to incrementally achieve project goals, aligning with ‘Flexibility Feature – 2 (Repetitiveness through Iterations)’ and ‘Flexibility Feature – 5 (Openness to Improvement and Adaptation)’.

Step – 8 (Feedback & Update): The final step is the 'Feedback & Update' process, marking the end of the current iteration and the beginning of the next iteration. However, if all milestones are completed, the implementation of the Integrated Procedure concludes. During the 'Feedback & Update' process, data flows from the 'Monitoring & Control' process and the 'Schedule Controlling' process of project schedule management. The next iteration commences with the 'Complexity Assessment Based on TOE Framework' and 'Risk Identification and Classification' processes, utilizing data transferred from the 'Feedback & Update' process in line with 'Flexibility Feature – 5 (Openness to Improvement and Adaptation)' and 'Flexibility Feature – 6 (Incremental Convergence)'. Additionally, the 'Schedule Development' process of project schedule management is supported by data from the 'Feedback & Update' process, as illustrated in Fig. 3. This interface aligns with 'Flexibility Feature – 10 (Integrability with Schedule Management Models)'. Moreover, the procedure can be repeated for different project phases, ensuring 'Flexibility Feature – 9 (Adaptability across Project Phases)'.

5. Example Application

This section demonstrates the retrospective application of the Integrated Procedure to the design phase of an irrigation project. The purpose is to show how the proposed procedure can be implemented and to evaluate the potential benefits that its usage can provide, compared to the actual situation where the Integrated Procedure was not implemented. Basic information regarding the project is provided below in italics:

The baseline schedule officially submitted to the Contracting Authority (Owner – the state institution responsible for water resources of the country where the project was carried out) by the Designer (the contractor responsible for the design) was a simple bar chart. There were 19 activities, and the project completion date on this approved schedule was set at 300 calendar days (provided in the 'Appendix B'). However, during the execution of the design phase, the Designer requested time extensions on several occasions from the Owner, and the Owner had to accept some of these requests in compliance with the contract conditions. As a result, the contractual (planned) project completion time of 300 calendar days increased to 683 days, resulting in a delay of 383 days in the actual project completion time.

Using this information, the steps of the procedure in Fig. 3 were applied retrospectively, based on a hypothetical scenario considering actual project conditions (participants of the project, external stakeholders, organizational structures of participants, etc.). The aim is to demonstrate how the Integrated Procedure can be implemented in practice and how it could have prevented such an unreasonably long delay if it had been implemented in the project under consideration. A detailed description of this example application is provided in the following sections. The hypothetical parts of the application, which are supposed to be performed based on a scenario, are presented in italics. Furthermore, Fig. 4, established based on Fig. 3, is provided below for the visual illustration of the steps followed, including the actors and tasks.

5.1. Complexity/risk management planning (Step 1)

Firstly, the participants (organized under the Designer and Owner) and external stakeholders (individuals or entities involved in the project) should be identified from the Designer's perspective. In this regard;

The participants were identified as the design, reporting, cost estimation, project risk assessment, and project scheduling units of the Designer; the design & construction, planning, expropriation, geotechnical, maintenance & operation, and project risk management units of the Owner; and the regional office (Contracting Authority) within the Owner's organization. Additionally, external stakeholders were identified as farmers (end-users) and farmer associations, politicians responsible for the region, environmental associations (regional or nationwide), and regional authorities (municipality, village representatives).

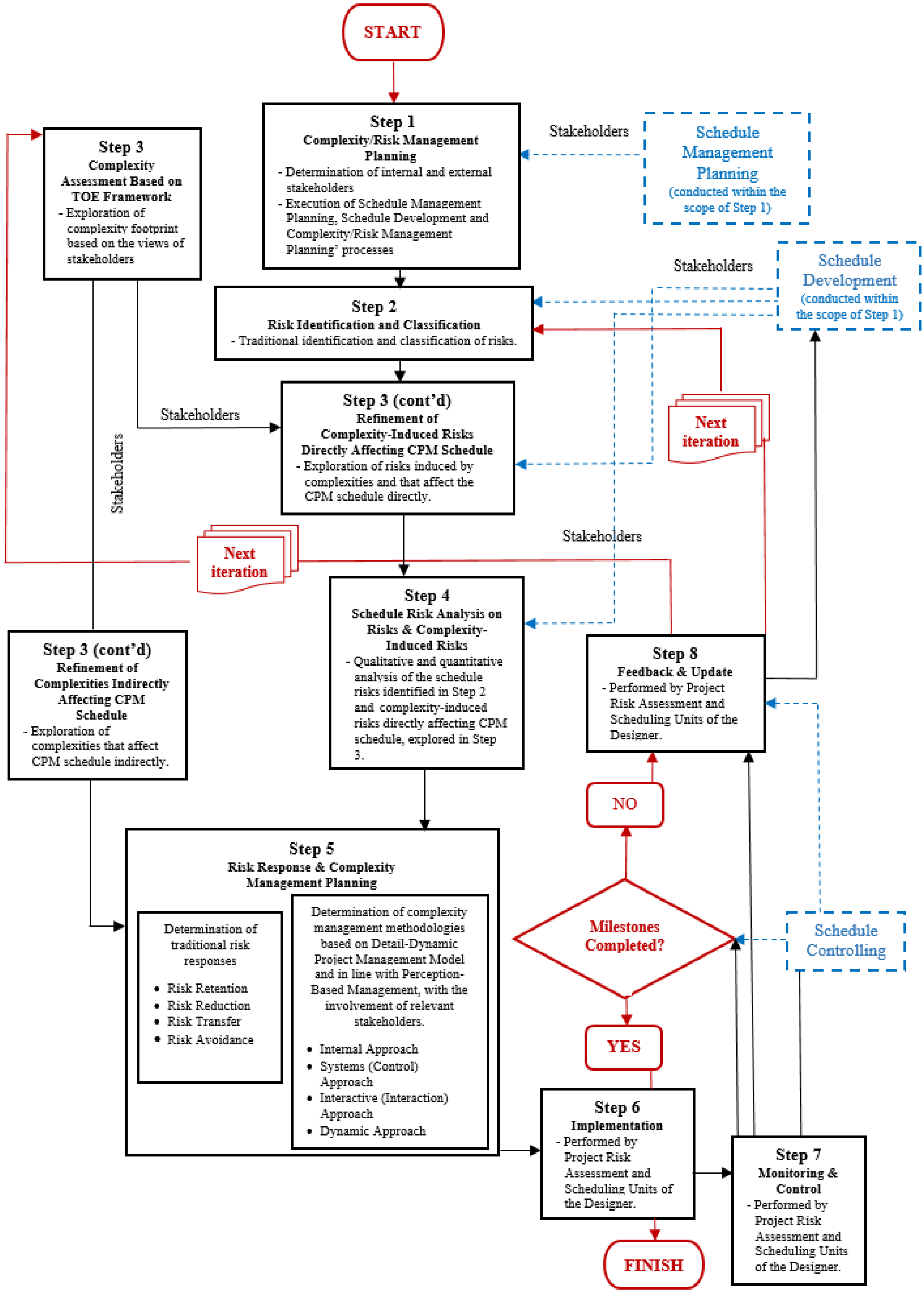

Fig. 4. Illustration of the steps followed in implementing the Integrated Procedure on the project

Next, the planning processes, namely the 'Schedule Management Planning', 'Schedule Development', and 'Complexity/Risk Management Planning' should be carried out (refer to Figs. 3 and 4). These processes address the procedures and plans that should be followed regarding how project schedule management, project risk management, and complexity assessment will be conducted. The information includes, but is not limited to, staffing, organizing, assignment of responsibilities, resources to be utilized, and the number of meetings. Tools and methods to be used should all be decided and included in a plan. The Critical Path Method (CPM) schedule of the project should be prepared through the Schedule Development process in consultation with the relevant participants and external stakeholders. Accordingly;

The approved official bar chart was transformed into an activity network to which the CPM could be applied. This was done using the same activity durations as those in the bar chart schedule to maintain compatibility between the two schedules (refer to the Appendixes C and D for the data used to construct the CPM schedule and the network diagram). However, the conversion from the bar chart schedule to the CPM schedule increased the project completion time from 300 calendar days (contractual/planned) to 316 days, as shown in the 'Appendix E'. This slight increase, which can be considered acceptable in terms of maintaining compatibility between the two schedules, is a result of reorganizing scheduling activities, establishing precedence relationships between activities, and implementing CPM's algorithm in this new configuration.

5.2. Risk identification & classification and complexity assessment based on TOE framework (Steps 2 and 3)

The next step involves the 'Risk Identification & Classification' and the 'Complexity Assessment Based on TOE Framework':

Brainstorming meetings were conducted during which the complexity elements in the TOE Framework were scored by the participants. After gathering the scores provided by different respondents, the mean values of the scores assigned to each complexity element were calculated. Subsequently, the complexity footprint of the project was determined based on prioritizing the complexity elements (details provided in the 'Appendix F'). The complexity footprint obtained through the implementation of the process 'Complexity Assessment based on TOE Framework' comprises the following:

- *Technical complexities: technical risks, involvement of different technical disciplines, dependencies between tasks, high variety of tasks, high number of tasks, number of locations, and project duration.*
- *Organizational complexities: organizational risks, interfaces between different disciplines, lack of experience with parties involved, lack of resources & skills availability, and high project schedule drive.*
- *External complexities: external risks, number of external stakeholders, variety of external stakeholders' perspectives, dependencies on external stakeholders, political influence, and interference with existing site.*

Since the complexity assessment conducted aims to explore all the complexities affecting the project, the complexities indirectly affecting the CPM schedule should be refined based on the 'Refinement of Complexities Indirectly Affecting CPM Schedule' process as shown in Figs. 3 and 4. The complexities refined in this manner should then be directly transferred to the 'Risk Response & Complexity Management Planning' process. On the other hand, the refinement of the complexity-induced risks directly affecting the CPM schedule should be carried out through another process, namely the 'Refinement of Complexity-Induced Risks Directly Affecting CPM Schedule'. This process comes after the 'Risk Identification & Classification' process, as demonstrated in Figs. 3 and 4. The details and findings of these two separate risk refinement processes are explained below:

Using the explored complexity footprint, the complexities indirectly affecting the CPM schedule were refined interactively with the involvement of relevant project participants and external *stakeholders. The complexities selected for inclusion in this group and directly transferred to the "Risk Mitigation & Complexity Management Planning" process (refer to Figs. 3 and 4) were as follows:*

- *Technical complexities: involvement of different technical disciplines, dependencies between tasks, high variety of tasks, high number of tasks, and number of locations.*
- *Organizational complexities: interfaces between different disciplines, lack of experience with parties involved, lack of resources & skills availability, and high project schedule drive.*
- *External complexities: number of external stakeholders, variety of external stakeholders' perspectives, dependencies on external stakeholders, and political influence.*

Subsequently, the complexities directly affecting the CPM schedule, namely 'technical risks, project duration, organizational risks, external risks, interference with the existing site', were filtered from the complexity footprint. This task was also carried out interactively with the involvement of relevant project participants and external stakeholders.

The 'Project Duration' complexity, also considered as one of the complexity-induced risks affecting the CPM schedule, was taken into account during the quantitative risk analysis in the subsequent process. The complexity related to 'Interference with the existing site' was considered as a source for risks directly affecting the CPM schedule (referred to as complexity-induced risks) during the "Risk Identification & Classification" process. The risks categorized under the complexities, such as technical risks, organizational risks, and external risks, were identified during this process. Later, these risks were utilized during the CSRAM application after distinguishing schedule risks from other project risks associated with technical, organizational, and external complexities.

The risks identified at the end of the 'Risk Identification & Classification' and 'Refinement of Complexity-Induced Risks Directly Affecting CPM Schedule' processes are listed below. These risks were considered impactful on the CPM schedule and were used in the subsequent step during the execution of risk analysis:

- *Technical Risks: design changes requested by the Design & Construction Unit, design changes requested by the Regional Office, disputes with the Design & Construction Unit on technical and contractual issues, disputes with the Regional Office on technical and contractual issues, change in crop pattern over time with respect to the Planning Report, design changes inside the organization of the Designer.*
- *Organizational Risks: late approval of design documents by the Design & Construction Unit, late approval of design documents by the Regional Office, Owner's delay in payments, inconsistent data & design parameters existing in the Planning Report, prolongation of the decision-making on design prior to the approval of the Initial Report, delay in written communication within the Owner's organization, low productivity among the staff of Designer, staff shortage within the organization of Designer, lack of experience and skill among the staff of Designer.*
- *External Risks: bad weather conditions during the site investigation, rejections to land expropriation by farmers, rejections to project by local authorities, political influence on project.*

5.3. Schedule risk analysis on risks & complexity-induced risks (Step 4)

In the previous steps, three groups of factors presumably effective on the CPM schedule were determined:

- The first group includes complexities that indirectly influence the CPM schedule. These complexities are transferred to the 'Risk Response & Complexity Management Planning' process (refer to Figs. 3 and 4), which is addressed in the next step.
- The second group comprises complexity-induced risks directly affecting the CPM schedule. These risks are utilized during the quantitative risk analysis process, specifically during the 'Schedule Risk Analysis' phase.

- The third group involves risks considered to affect the CPM schedule, which are traditionally identified and classified using risk identification methods under the categories of 'technical, organizational, and external'. These risks also correspond to the complexity elements of "technical risks", "organizational risks", and "external risks" outlined within the TOE Framework.

Complexities and risks deemed not to affect the CPM schedule are disregarded. As demonstrated in Figs. 3 and 4, the process that follows risk identification and complexity assessment is the implementation of 'Schedule Risk Analysis' on the identified risks and complexity-induced risks. This process comprises two subsequent tasks: qualitative risk analysis and quantitative risk analysis:

The risks were categorized as high, medium, or low based on their 'occurrence probability x impact level' values during the qualitative risk analysis. Risks receiving a high priority during this analysis, along with the previously identified complexity-induced risks, were directly transferred to the quantitative risk analysis stage (refer to the 'Appendix G'). Subsequently, the data required for the Correlated Schedule Risk Analysis Model (CSRAM) application was determined. This data included the estimated minimum (optimistic), most likely and maximum (pessimistic) activity durations, which were used to represent the activity durations in the CSRAM application. Additionally, the CSRAM application needed the network and predecessor relationships between activities utilized in the CPM application, risk factors affecting the activity durations, influence degrees of the risk factors on the activity durations, and the correlation information between the risk factors (refer to the 'Appendix H'). Further details about the CSRAM application can be found in the 'Appendixes I and J'. Fig. 5 illustrates the uncertainty regarding project duration based on the results obtained from the Bar Chart Method, CPM, and CSRAM applications. While the project completion time is deterministically set at 300 days (as stipulated by the contract) in the Bar Chart schedule and calculated as 316 days according to the CPM schedule (refer to the 'Appendixes B and E'), CSRAM models the uncertainty surrounding project completion time in a stochastic manner and presents it as a cumulative probability curve.

As previously mentioned, the example project was completed in 683 days, exceeding the contractual project duration by 383 days. It is crucial for the Designer to be aware of the probabilities associated with various project durations during the upcoming "Risk Mitigation/Complexity Management Planning" process. Table 3 displays the results obtained through the CSRAM application regarding project duration uncertainty and project/risk sensitivity. When all risks were simultaneously simulated in the CSRAM application, the minimum, mean, and maximum expected project durations were calculated as 281, 457, and 735 days, respectively.

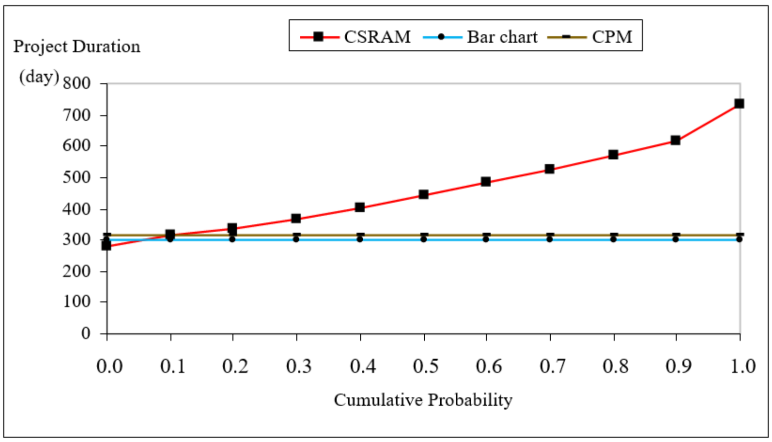

Fig. 5. Results of Bar Chart Method, CPM, and CSRAM applications on project duration uncertainty

Table 3. Results of CSRAM application on duration uncertainty and project/risk sensitivity

Scenario	Minimum Project Duration (day)	Mean Project Duration (day)	Maximum Project Duration (day)	Standard Deviation of Project Duration	Coefficient of Variation	Sensitivity Rank
All Risks	281.41	457.09	735.45	113.52	-	-
Risk 1 (Design changes inside the organization of the Designer)	308.47	315.42	328.03	4.91	0.02	3
Risk 2 (Design changes requested by the Regional Office)	312.83	316.99	364.44	6.04	0.02	3
Risks 3 ~ 4 (*Correlated*) (Design changes requested by the Design & Construction Unit ~ Late approval of design documents by the Design & Construction Unit)	295.93	450.39	659.20	114.71	0.25	1
Risk 5 (Low productivity among the staff of Designer)	299.37	326.06	362.79	17.64	0.05	2
Risk 6 (Staff shortage within the organization of Designer)	303.61	316.11	335.41	5.46	0.02	3
Risk 7 (Bad weather conditions during the site investigation)	311.91	316.45	321.47	2.13	0.01	4
Risk 8 (Owner's delay in payment)	312.04	316.66	326.79	3.52	0.01	4
Risk 9 (Disputes with the Design & Construction Unit on technical and contractual issues)	311.22	321.54	378.68	16.73	0.05	2
Risk 10 (Delay in written communication within the Owner's organization)	314.88	317.71	322.92	2.57	0.01	4

In this scenario, both the contractual project duration (300 days) and the actual project duration achieved upon project completion (683 days) fall within the range suggested by CSRAM. Moreover, it is important for the Designer to understand the project duration's sensitivity to risks. Table 3 indicates that risks 3, 4, 5, and 9 significantly impact the project duration. As mentioned earlier, the Designer requested time extensions from the Owner on multiple occasions after the project had commenced, and the Owner had to approve some of these requests as per the contract terms. Reviewing relevant project documents revealed that the project duration's sensitivity to the risks outlined in Table 3 aligns with the primary reasons for the schedule delay experienced during the design phase of the project.

5.4. Risk response & complexity management planning (Step 5)

The next step in the Integrated Procedure (refer to Figs. 3 and 4), namely the 'Risk Response & Complexity Management Planning', should be implemented using traditional risk response procedures and complexity management methodologies proposed by the Detail-Dynamic Project Management Model. To address the complexity footprint and propose a tailored management strategy aligned with Perception-Based Management without disregarding the subjective nature of complexity, the project's relevant participants should be engaged in the process. This involvement will occur through meetings scheduled in the Complexity/Risk Management Plan.

5.5. Implementation, monitoring & control, feedback & update and the next iteration after the first milestone (Steps 6 - 8)

The next processes that the Project Risk Assessment and Scheduling Units of the Designer should carry out are the 'Implementation', 'Monitoring & Control', and 'Feedback & Update' processes, the steps 6 to 8 (refer to Fig. 3). While the 'Monitoring & Control' process is conducted in relation to the 'Schedule Control' process of project schedule management, the 'Feedback & Update' process is carried out in relation to the 'Schedule Development' process of project schedule management, with the involvement of relevant stakeholders.

Since all processes of the Integrated Procedure are to be implemented through successive iterations after completing each milestone assigned in the CPM schedule, the Designer should assess the progress achieved up to the milestone determined on the CPM schedule using relevant processes of Project Schedule Management. Subsequently, they should continue with the next iteration (refer to Figs. 3 and 4). This iterative approach provides the required flexibility and allows the Designer to leverage various managerial flexibilities inherent in the CPM, as well as expand the managerial flexibilities in the CPM schedule based on the use of the CSRAM. Moreover, incorporating the TOE Complexity Assessment Framework into project risk management and utilizing the Detail-Dynamic Project Management Model based on Perception-Based Management and Fit-for-Purpose Management enhances the dynamism of schedule management. This, in turn, enriches the managerial flexibilities required by the Designer to address complexities and uncertainties and complete the project on time.

5.6. Discussion of results

If the Designer had utilized the results of the schedule risk analysis process during both the contracting stage and the preparation of the baseline CPM schedule, instead of relying solely on a bar chart schedule (as was the case in reality), she would have had the opportunity to incorporate the identified complexities and schedule risks into the risk mitigation and complexity management strategies. This integration could have been done during the project's execution. As a result, a more realistic project completion time could have been proposed to the Owner, a superior CPM-based schedule could have been submitted at the project's outset, and the schedule delays experienced in reality could have been largely prevented. This would have been achieved by managing the CPM schedule in accordance with the risk mitigation/complexity management strategies and leveraging the managerial flexibilities provided by both the traditional CPM and its extension, the CSRAM.

The following three examples (the first one is representative for the risks and the other two are representative for the complexities directly and indirectly effective on the schedule, respectively) present the strategies that could be proposed on behalf of the Designer to mitigate the risks and manage the complexities effective on the CPM schedule, considering the actual story of the project and the results of the application of the Integrated Procedure:

- *Design changes requested by the Design & Construction Unit and Late approval of design documents by the Design & Construction Unit:* These are risks 3 and 4, respectively, used as correlated risk factors during the CSRAM application. According to the results of CSRAM regarding project/risk sensitivity given in Table 3, the CPM schedule is most sensitive to these two correlated risk factors. The project duration envisaged through the CPM schedule may be extensively impacted due to the uncertainty created by these correlated risks. The time extension requests delivered to the Owner by the Designer during project execution were mainly due to the combined effect of these risks. Therefore, the Designer should have taken several measures. Firstly, she should have applied risk control measures to ensure the timely approval of design documents by the Regional Office and the prompt submission of these documents by the Regional Office to the Central Office. Secondly, she should have established strong communication channels with the relevant units of the Project & Construction Department through highly skilled design staff. Thirdly, she should have closely followed the approval process within the Owner's organization to prevent any delay or oversight regarding the design documents. Another cause of the schedule overrun in the project was the technical meetings held within the Design & Construction Unit, involving various internal and external stakeholders, before the preparation of the 'Pre-Design (Initial) Technical Report'. In these meetings, major design changes were decided by the Owner due to inaccuracies in the design formulation presented within the 'Planning (Feasibility) Report'. These design changes led to schedule overrun and time extension requests by the Designer. Therefore, the Designer should have taken necessary measures to address potential technical problems arising from deficiencies in the 'Planning Report'. As a proactive measure, she could have alerted the Owner about these deficiencies earlier by instructing experienced and highly skilled staff to thoroughly review the Planning Report before the relevant meetings were held. This would have allowed for better preparation and potentially avoided the need for major design changes later in the project, thus preventing schedule overruns and time extensions.

• *Project Duration:* All the effort put into managing the CPM schedule aims to control and embrace this complexity to ensure timely project completion. In this regard, this complexity is significant from the scheduling perspective. Comparing the contractual project duration of 300 days determined based on the bar chart schedule, the 316 days calculated by CPM, the cumulative probability curve of project duration forecasted by CSRAM, and the actual project duration at completion (683 days), it is evident that the Designer should have submitted a CPM schedule to the Owner instead of a bar chart schedule, resulting in a more achievable project duration. The cumulative probability curve of project duration in Fig. 5 illustrates that, according to CSRAM, the minimum, mean, and maximum expected project durations are 281, 457, and 735 days, respectively. The decision to adopt a CPM schedule over a bar chart schedule would have depended on the Designer's risk attitude and past experiences. Additionally, the project/risk sensitivity of the CPM schedule explored by CSRAM (refer to Table 3) should have been considered during project management. Being aware of the most impactful risks that cause variations in activity durations is crucial for allocating efforts and resources effectively. Moreover, the Designer should have leveraged the managerial flexibilities provided by CPM and the variations in these flexibilities disclosed by CSRAM during project execution. This could have been achieved by using appropriate project scheduling software to fully utilize these managerial flexibilities.

• *Variety of external stakeholders' perspectives:* The presence of external stakeholders such as farmers, regional authorities, and politicians can be considered a source of complexity, particularly regarding the variety of perspectives among these stakeholders. Additionally, differing perspectives may exist between the Regional Office and the Design & Construction Unit. Since irrigation projects ultimately serve the agriculture sector, various external stakeholders with conflicting interests and perspectives may influence these projects during the design and construction phases. Therefore, the Designer should have implemented a fit-for-purpose strategy tailored to manage this complexity, leveraging opportunities and creating value for the project. Given the dynamic nature of this complexity, an interactive approach would have been beneficial, aligning with the principles of the Detail-Dynamic Management Model. The Designer should have adopted an interactive approach to establish effective communication channels with external stakeholders, aiming to transform this complexity into an opportunity and align goals among stakeholders to create value for the project.

The main reasons for the project taking 683 days to complete, with a significant delay, include several factors. Firstly, the inadequacy of the bar chart schedule in effectively managing a complex project contributed to the delay. Secondly, inaccuracies in schedule predictions, coupled with the absence of risk analysis and risk management processes, further exacerbated the situation. Thirdly, there was a lack of awareness regarding the inherent complexities of the project, and insufficient consideration of the demands and suggestions from internal and external stakeholders. It is evident that a simple bar chart schedule was unable to reveal the dependencies between activities and critical activities that directly impact project duration. Moreover, the failure to implement necessary processes, particularly in the areas of project risk management and project schedule management, meant that the effects of various risks, uncertainties, and complexities on the schedule were not identified and managed. Additionally, the interactive and flexible conditions essential for successfully managing such projects were not established due to neglecting external stakeholders, such as farmers who would ultimately use the project as end-users.

6. Conclusions and Recommendations

This study addresses project risk management within the framework of schedule management, while also considering complexity and flexibility. With complexity and high uncertainty becoming challenging aspects of large-scale engineering projects, the adoption of flexibility in managing such projects is crucial for success. In this context, the procedure proposed in this study, named the 'Integrated Flexible Schedule Complexity/Risk Management (IFSCRM) Procedure' or simply the 'Integrated Procedure', aims to help manage schedule risks flexibly while acknowledging complexities and the interaction of schedule risk management with schedule management processes. This approach bridges theory and practice, expands beyond the conventional territory of traditional project risk management, and contributes to practice by enhancing schedule management practices. In addition, it is aimed to provide support to decision-making and policy-formation processes in engineering organizations from the aforementioned perspective.

The procedure was applied to the design phase of a project retrospectively and hypothetically using actual project information. By this way, alongside to its applicability, contributions that could have been provided in case it was implemented were revealed. Furthermore, the points on which improvement could be provided from the scheduling perspective were figured out. The managerial advantages were compared with the actual story of the project. The project suffered from a long schedule delay at completion. The interaction with the stakeholders, their involvement into the processes, adoption of perception-based management and in turn, establishment of a shared-mental model through the perceived complexities were found to be the key focus areas that were missing and therefore led to time extensions. It was concluded that when responding to schedule risks, rather than trying to reduce the complexities (something that is not actually easy to achieve most of the time), embracing complexities to take the advantage of opportunities should be the strategy to follow to establish appropriate fit-for-purpose management and thus the way to obtain enhanced risk responses.

The results of the application also indicated that integrating complexity assessment has the potential to enhance risk identification and analysis. This leads to a more thorough evaluation of uncertainty regarding various aspects of schedules, such as project completion time and risk sensitivity. Furthermore, integrating flexibility enablers into the overall framework of schedule and risk management processes, and adopting flexible approaches when addressing risks, can result in the development of improved fit-for-purpose responses to risks. This advantage can significantly contribute to achieving success in schedule management.

Based on the relevant literature, this study can be considered a pioneering effort in its field, particularly because previous studies have been noted for their gap in not addressing risk management with a focus on scheduling, as well as from the perspectives of complexity, flexibility, and the interaction of risk management with schedule management. This study aims to contribute to filling this gap and initiate a discussion on the necessity of incorporating flexibility into project management across various dimensions. The strength of the proposed procedure lies in its ability to leverage complexity assessment and management methodologies, harness the inherent flexibilities of CPM, leverage additional flexibilities provided by schedule risk analysis modeling, and incorporate a set of features that enable flexibility in project management. This inductive approach combines the strengths of these methodologies and creates a practical integrated procedure for flexibly managing schedule risks in engineering projects under complex conditions.

However, the developed procedure also has several limitations that could be addressed in future research. Firstly, it is solely based on CPM scheduling. While CPM is the most widely used method for scheduling activity networks, it may not be suitable for scheduling repetitive or linear projects such as highways, railways, and multi-story buildings. In such projects, there is often a need to combine CPM with linear scheduling methods, and this combination should be included in the proposed procedure. Secondly, the relationships and interactions between risks and complexities should not be overlooked when using the procedure. In this regard, previously developed methods can be integrated into the procedure to assess complexity-induced risks and complexities affecting schedules. Thirdly, future research can be conducted regarding ‘strategic behavior’ such as ‘creative lying’ and ‘ignorance-based omissions’ to investigate whether the procedure would indeed be effective in managing such behaviors and reducing their adverse impact on the risk identification process. Finally, the procedure should be applied on a real-time basis to observe its advantages and disadvantages, and to ensure continuous improvement. As the number of projects utilizing the ‘Integrated Procedure’ in real-time increases, the actual project completion times of these projects can be compared with the project completion times of previously completed similar projects. This comparison will allow evaluating the extent to which the proposed method is promising in achieving the project objectives in terms of schedule.

Engineering organizations could benefit from the approach proposed in this study to address schedule risks along with complexities, manage schedule risks flexibly, and consequently improve the schedule management processes of their projects. This will provide an advantage in successfully completing complex projects undertaken amidst high uncertainty. Furthermore, the decision-making processes regarding engineering organizations’ projects will improve, enabling better decisions due to enhanced complexity management methodologies activated alongside the various flexible features embedded in the proposed procedure to adapt to dynamic project conditions.

The traditional plan-oriented approach, which has been the dominant method in project management, has recently been evolving towards a more change-oriented and flexible form. This evolution is driven by the necessity to adapt to project dynamics, complexities, and uncertainties. Alternatively, these two main perspectives can be balanced and tailored through a hybrid approach that considers the specific needs and conditions of projects, rather than applying a purely flexible approach such as agile project management methodology. In other words, rather than strictly adhering to the traditional plan-oriented paradigm of project management, transitioning to a flexible, change-oriented management mode through hybrid approaches inspired by modern project management, as suggested in this study, appears to be a necessity for organizations operating in the engineering industry. This shift can help them achieve success in complex projects and gain an advantage in today's fiercely competitive environment.

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Author Contributions

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

Not applicable.

Conflict of Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A

The methods used to develop the approach proposed in this study.

The approach proposed in this study requires the use of a number of previously developed methods, which are described below briefly along with the reasons of their use in this study. Detailed information can be obtained from the references listed below, the details of which are given in the reference list of the article.

- *Critical Path Method (CPM) Scheduling:* Critical Path Method (CPM) Scheduling is a popular and widely used method for scheduling activities in a project that are interconnected on a network basis. It considers logical constraints between activities in terms of precedence, as well as other limitations such as resource availability. Detailed information about CPM can be found in references [1, 38–40]. Due to its importance, advantages, widespread usage, and flexible features [41], CPM has been the primary scheduling method focused on in this study.
- *Correlated Schedule Risk Analysis Model (CSRAM):* CSRAM was developed as a simulation-based schedule risk analysis method, specifically using Monte Carlo Simulation (MCS) [42, 43], to be applied to CPM schedules. With CSRAM, it becomes possible to model variations in activity durations and project completion time by simulating real-life conditions stochastically through MCS, taking into account correlations between activities and among risks. Due to its distinguishable feature of capturing this two-sided correlation effect, along with its other important features, CSRAM has been the CPM-based schedule risk analysis method utilized in this study.
- *Schedule and risk management processes of the Project Management Body of Knowledge: (PMBOK):* The PMBOK 6 outlines 49 processes across five process groups related to 10 knowledge areas essential for successful project management [1]. This study focuses on the “Project Schedule Management” and “Project Risk Management” knowledge areas and their associated processes. PMBOK 7 [27] signifies a significant shift from process-based project management to principle-based delivery, which differs from PMBOK 6. This study also represents an attempt to transition between the sixth and seventh editions of the PMBOK Guide concerning schedule risk management. Specifically, it considers the complexity, holistic system thinking, tailoring principles of project delivery, and flexibility in management approaches promoted by PMBOK 7.
- *Technical, Organizational and External (TOE) Complexity Assessment Framework:* The “Technical, Organizational and External Complexity Assessment Framework” or “TOE Framework” was developed by Bosch-Rekveldt [44] for assessing the complexity of projects [12]. This framework encompasses 47 complexity elements categorized into three groups: technical, organizational, and external factors. Its utilization involves a scoring process that yields a complexity footprint of projects [12]. Due to its capacity to incorporate the subjective nature of complexity, its detailed categorization and disclosure of complexities, and its consideration of project risks as potential elements of project complexity, the TOE Framework has been the utilized method for complexity assessment in this study.
- *Detail-Dynamic Project Management Model:* The Detail-Dynamic Project Management Model was developed by Hertogh and Westerveld [2]. This model addresses project complexity across two dimensions: detail and dynamic complexity. Detail complexity relates to a high number of components and a significant degree of interrelatedness, whereas dynamic complexity pertains to the potential for change over time, limited comprehensibility, and predictability [2]. The model proposes various management approaches based on the levels of detail and dynamic complexity. Because it offers concrete solutions tailored to different situations based on the type and level of complexity anticipated, the Detail-Dynamic Project Management Model was employed as the complexity management methodology in this study.

- *Perception-Based Management:* Practitioners, in general, may have varying perceptions of complexity. Even individuals working within the same organization, on the same projects, and with similar roles, can identify entirely different complexities within the project. This phenomenon is known as "perceived complexities" or the "subjective nature of complexity" [45]. Managing perceived complexities is referred to as "Perception-Based Management" [45]. This approach adds value and facilitates the discovery of better solutions during project implementation by leveraging the diverse perceptions of stakeholders. Perception-Based Management was utilized as a flexibility enabler in this study.
- *Fit-for-Purpose Management:* The basic consideration behind Fit-for-Purpose Management is that every project has different features and context and therefore, the projects should be managed through fitting approaches or styles to the context. An ordinary project planning becomes insufficient due to the increased project dynamics [46]. For this reason, instead of approaching the projects in the same way as the traditional project management dominantly does, modern project management approaches consider projects as differing endeavors and claim the necessity to adapt the managerial practices to the specific purpose and context of each project [47], as the "Fit-for-Purpose Project Management" proposes [38]. In this study, Fit-for-Purpose Project Management was employed because it introduces flexibility to project management based on the fundamental notion that "one size does not fit all" [46].

Appendix B

The official bar chart schedule (approved by the Owner) of the project handled in the “Example Application” section of the paper.

Activity No. & Description	Duration (day)	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
1 - Submission of time schedule to Owner and approval	40												
2 - Submission of preliminary report to Owner	75												
3 - Approval of preliminary report by Owner	15												
4 - Submission of general layout plan to Owner & approval	30												
5 - Submission of upper plain plans and calculations to Owner	20												
6 - Approval of upper plain plans and calculations to Owner	40												
7 - Submission of pre-application design drawings of pipelines	70												
8 - Approval of pre-application design drawings of pipelines	60												
9 - Submission of hydraulic design drawings	70												
10 - Approval of hydraulic structure design drawings	40												
11 - Submission of operation and maintenance roads design drawings & approval	15												
12 - Submission of access road design drawings, related reports & approval	15												
13 - Submission of post-application design drawings of pumps & approval	40												
14 - Submission of architectural and static design drawings of pump stations & approval	15												
15 - Cost estimation and quantity measurement reports of pipelines & approval	8												
16 - Cost estimation and quantity measurement reports of hydraulic structures & approval	8												
17 - Submission of green dossier, project reports & approval	8												
18 - Submission, approval & reproduction of design documents' originals	8												
19 - Submission of final measurements and payment certificate & approval	8												

Project Start: 2nd of January

Project Finish: 28th of October (300 calendar days)

Appendix C

Activities and network information established to develop the CPM schedule for the project handled in the "Example Application" section of the paper.

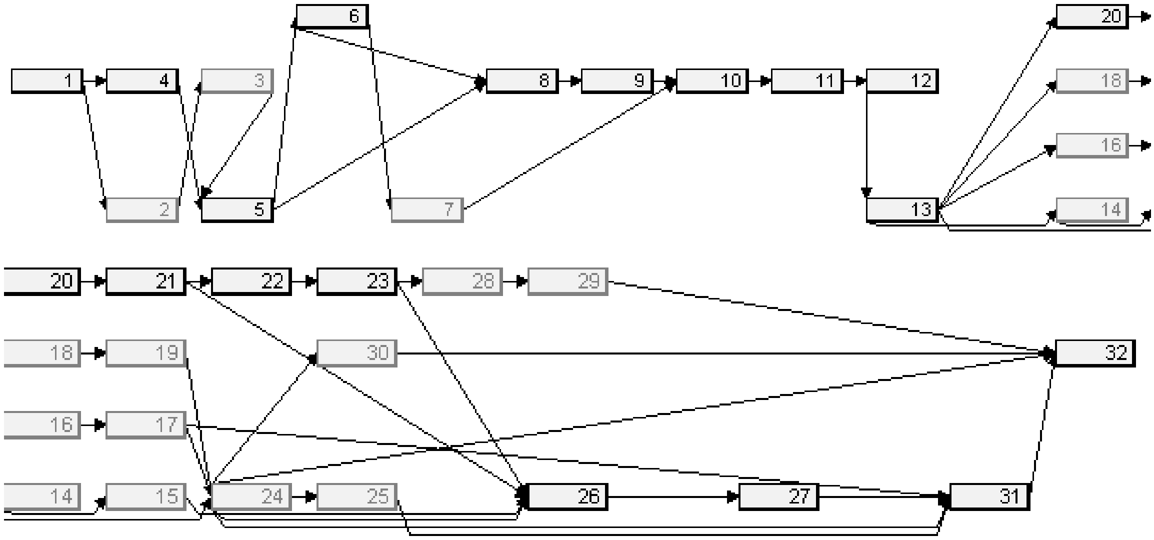
Activity No.	Activity Name	Activity Duration (day)	Predecessor activity & network relationship*
1	Work Takeover	1	-
2	Submission of work schedule to Owner	30	1 (FS)
3	Approval of work schedule by Owner	10	2 (FS)
4	Submission of initial report to Owner	75	1 (FS)
5	Approval of initial report by Owner	20	3 (FS) 4 (FS)
6	Submission of general layout plan to Owner	20	5 (FS)
7	Approval of general layout plan by Owner	10	6 (FS)
8	Submission of upper plain plans and calculations to Owner	15	5 (FS) +8 6 (SS) +13
9	Approval of upper plain plans and calculations by Owner	5	8 (FS)
10	Submission of pre-application design drawings to Owner	30	7 (FS) 9 (FS)
11	Approval of pre-application design drawings by Owner	10	10 (FS)
12	Submission of post-application design drawings to Owner	70	11 (FS)
13	Approval of post-application design drawings by Owner	60	12 (SS) +16
14	Submission of hydraulic structure design drawings to Owner	70	13 (SS) +10
15	Approval of hydraulic structure design drawings by Owner	40	14 (SS) +40
16	Submission of operation and maintenance roads design drawings to Owner	10	13 (FS)
17	Approval of operation and maintenance roads design drawings by Owner	5	16 (FS)
18	Submission of access road design drawings and reports to Owner	10	13 (FS)
19	Approval of access road design drawings and reports by Owner	5	18 (FS)
20	Submission of post-application design drawings of pumping elevation lines to Owner	30	13 (FS)
21	Approval of post-application design drawings of pumping elevation lines by Owner	10	20 (FS)
22	Submission of architectural and static design drawings of pumping stations to Owner	10	21 (FS)
23	Approval of architectural and static design drawings of pumping stations by Owner	5	22 (FS)
24	Submission of cost estimation and quantity measurement reports of pipelines to Owner	4	13 (FS) 17 (FS) 19 (FS)
25	Approval of cost estimation and quantity measurement reports of pipelines by Owner	4	24 (FS)
26	Submission of cost estimation and quantity measurement reports of hydraulic structures and pumping station to Owner	4	15 (FS) 21 (FS) 23 (FS) 24 (SS)
27	Approval of cost estimation and quantity measurement reports of hydraulic structures and pumping station by Owner	4	26 (FS)
28	Submission of green dossier and project reports to Owner	4	23 (FS)

			24 (SS)
29	Approval of green dossier and project reports by Owner	4	28 (FS)
30	Submission, approval and reproduction of design document originals	8	24 (SS)
31	Submission of final measurements and payment certificate to Owner	4	17 (FS) 25 (FS) 27 (FS) 24 (SS)
32	Approval of final measurements and payment certificate by Owner	4	29 (FS) 30 (FS) 31 (FS) 24 (SS)

*FS: Finish-to-Start, SS: Start-to-Start

Appendix D

CPM network diagram for the project handled in the “Example Application” section of the paper.



Appendix E

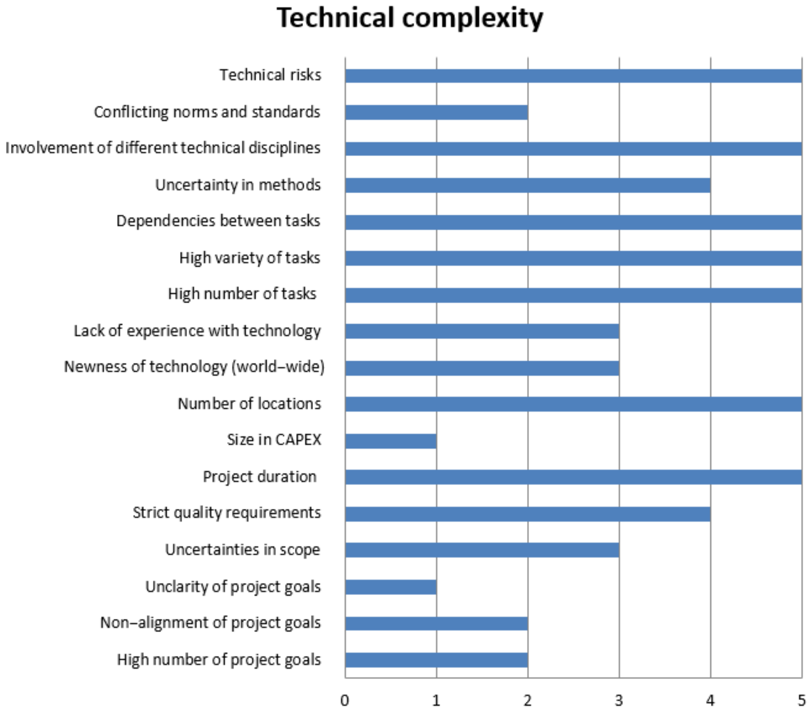
Results of the CPM application for the project handled in the "Example Application" section of the paper.

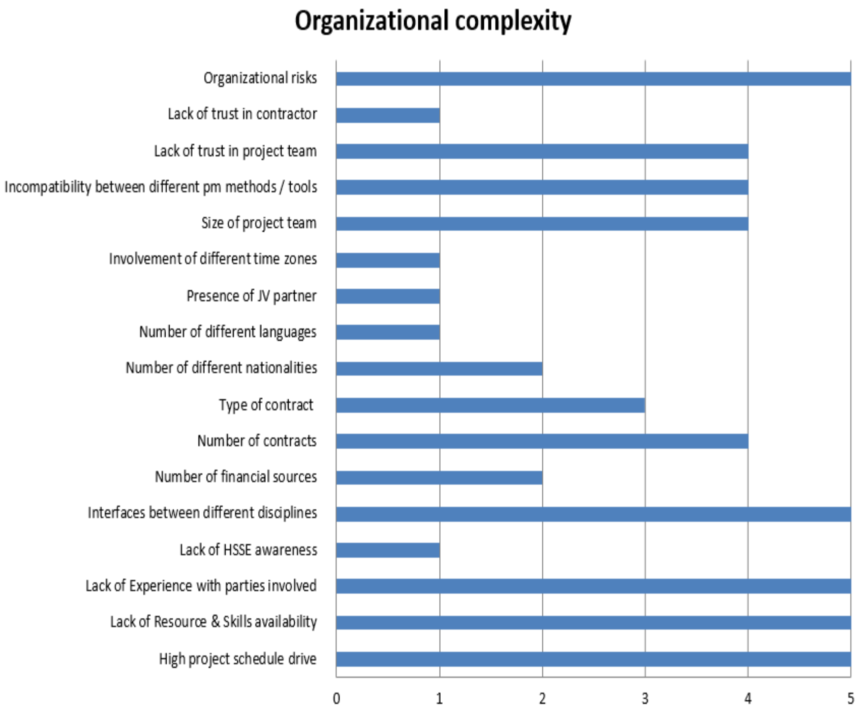
Activity No.	Early Start Time	Late Start Time	Early Finish Time	Late Finish Time	Free Float Time*	Shared Float Time	Independent Float Time	Total Float Time	Float Sharing Activity	Criticality
1	0	1	0	1	0	0	0	0	-	Critical
2	1	31	36	66	0	35	0	35	3	Noncritical
3	31	41	66	76	35	35	0	35	2	Noncritical
4	1	76	1	76	0	0	0	0	-	Critical
5	76	96	76	96	0	0	0	0	-	Critical
6	96	116	96	116	0	0	0	0	-	Critical
7	116	126	119	129	3	0	3	3	-	Noncritical
8	109	124	109	124	0	0	0	0	-	Critical
9	124	129	124	129	0	0	0	0	-	Critical
10	129	159	129	159	0	0	0	0	-	Critical
11	159	169	159	169	0	0	0	0	-	Critical
12	169	239	169	239	0	0	0	0	-	Critical
13	185	245	185	245	0	0	0	0	-	Critical
14	195	265	220	290	0	25	0	25	15	Noncritical
15	235	275	260	300	25	25	0	25	14	Noncritical
16	245	255	285	295	0	40	0	40	17,18,19	Noncritical
17	255	260	295	300	0	40	0	40	16,18,19	Noncritical
18	245	255	285	295	0	40	0	40	16,17,19	Noncritical
19	255	260	295	300	0	40	0	40	16,17,18	Noncritical
20	245	275	245	275	0	0	0	0	-	Critical
21	275	285	275	285	0	0	0	0	-	Critical
22	285	295	285	295	0	0	0	0	-	Critical
23	295	300	295	300	0	0	0	0	-	Critical
24	260	264	300	304	0	40	0	40	30	Noncritical
25	264,	268	304	308	40	0	0	40		Noncritical
26	300	304	300	304	0	0	0	0		Critical
27	304	308	304	308	0	0	0	0		Critical
28	300	304	304	308	0	4	0	4	29	Noncritical
29	304	308	308	312	4	4	0	4	28	Noncritical
30	260	268	304	312	44	40	4	44	24	Noncritical
31	308	312	308	312	0	0	0	0		Critical
32	312	316	312	316*	0	0	0	0	-	Critical

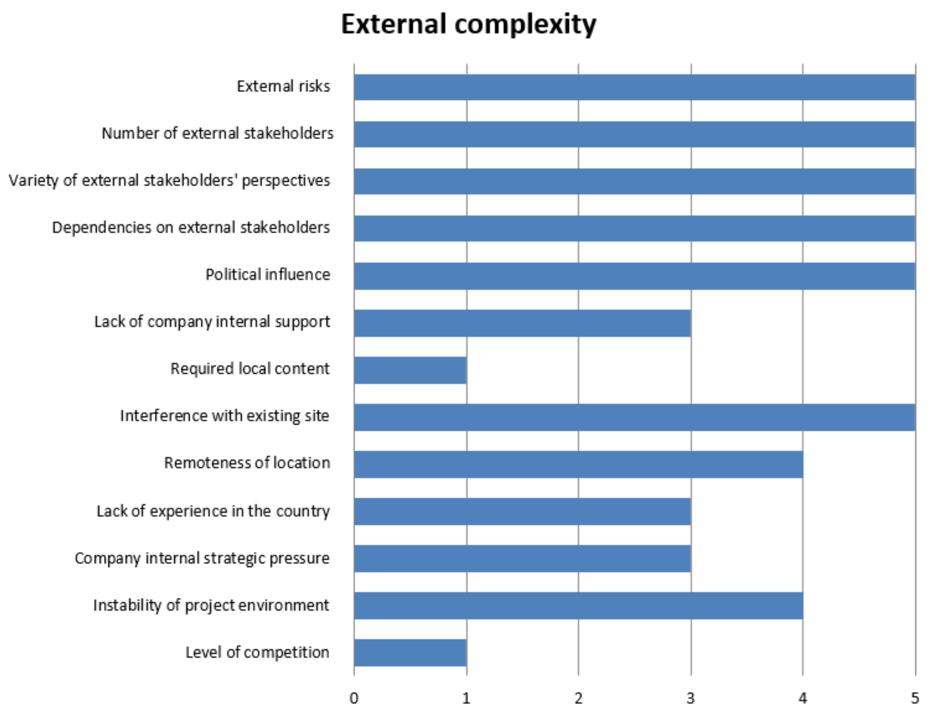
*Project Completion Time in "days".

Appendix F

Results of the 'Complexity Assessment based on TOE Framework' process implemented for the project handled in the "Example Application" section of the paper.







Complexity Footprint

- **Technical**
    - Technical Risks
    - Involvement of different technical disciplines
    - Dependencies between tasks
    - High variety of tasks
    - High number of tasks
    - Number of locations
    - Project Duration
- **Organisational**
    - Organisational Risks
    - Interfaces between different disciplines
    - Lack of experience with parties involved
    - Lack of resources & skills availability
    - High project schedule drive
- **External**
    - External Risks
    - Number of external stakeholders
    - Variety of external stakeholders' perspectives
    - Dependencies on external stakeholders
    - Political influence
    - Interference with existing site

Appendix G

Results of the qualitative risk analysis performed for the project handled in the "Example Application" section of the paper.

Risk No.	Category	Description	Occurrence Probability (P)	Impact Level (I)	P x I	Priority
1	Technical	Design changes requested by the Design & Construction Unit	0.9	9	8.1	High
2	Technical	Design changes requested by the Regional Office	0.8	9	7.2	High
3	Technical	Disputes with the Design & Construction Unit on technical and contractual issues	0.8	9	7.2	High
4	Technical	Disputes with the Regional Office on technical and contractual issues	0.8	7	5.6	Medium
5	Technical	Change in crop pattern over time with respect to the Planning Report	0.6	7	4.2	Medium
6	Technical	Design changes inside the organization of the Designer	0.9	9	8.1	High
7	Organizational	Late approval of design documents by the Design & Construction Unit	0.9	10	9.0	High
8	Organizational	Late approval of design documents by the Regional Office	0.7	9	6.3	Medium
9	Organizational	Owner's delay in payments	0.8	9	7.2	High
10	Organizational	Inconsistent data & design parameters existing in the Planning Report	0.6	8	4.8	Medium
11	Organizational	Prolongation of the decision-making on design prior to the approval of the Initial Report	0.7	8	5.6	Medium
12	Organizational	Delay in written communication within the Owner's organization	0.8	9	7.2	High
13	Organizational	Low productivity among the staff of Designer	0.9	9	8.1	High
14	Organizational	Staff shortage within the organization of Designer	0.8	9	7.2	High
15	Organizational	Lack of experience and skill among the staff of Designer	0.7	9	6.3	Medium
16	External	Rejections to land expropriation by farmers	0.6	6	3.6	Medium
17	External	Rejections to project by local authorities	0.3	4	1.2	Low
18	External	Political influence on project	0.4	7	2.8	Low

Appendix H

Brief Explanation about Correlated Schedule Risk Analysis Method (CSRAM). *(Source: the references [50] and [60] in the reference list of the paper)*

CSRAM was created as a method for analyzing schedule risks, designed to be applied in the risk management procedures of construction projects. This approach was developed by integrating Monte Carlo Simulation (MCS) with the Critical Path Method (CPM). MCS is a simulation technique used for quantitative risk analysis in projects, facilitated by specialized spreadsheet software like @Risk® and Crystal Ball®. This technique allows for the stochastic simulation of real-world conditions such as cost estimates and project timelines, which would be challenging to achieve through analytical methods alone. Using algorithms embedded within CSRAM, MCS generates random variables based on the statistical characteristics of input data. After each MCS iteration, which involves multiple CPM applications, statistical data is gathered to highlight potential variations in various project aspects caused by uncertainty during project execution.

Each CPM iteration generated by MCS within CSRAM represents a distinct scenario for the project based on CPM. Essentially, the risk factors assumed to influence a project exhibit varied patterns (i.e. better than expected or worse than expected) in each CPM run during the simulation. CSRAM randomly selects the data used in each CPM run while considering potential correlations between activities and risk factors (referred to as 'two-sided' correlations). In this process, qualitative data is employed and inputted into CSRAM to indirectly capture these correlations, avoiding explicit requests for correlation coefficients. These 'two-sided' correlations can significantly heighten uncertainty in CPM schedules. Thus, disregarding these correlations between activities and risk factors would lead to inaccurate results when assessing the impacts of uncertainty on a CPM schedule. Consequently, CSRAM is designed to model the effect of these two-sided correlations.

The model employs qualitative data input for the random selection of activity durations in each CPM iteration. As CSRAM extends CPM stochastically, activity durations are described to CSRAM through three estimations: the most likely duration, the minimum duration (optimistic), and the maximum duration (pessimistic), in contrast to CPM's single duration estimate. CSRAM then randomly chooses activity durations from within these estimated time intervals, guided by the provided risk and correlation data.

The algorithm of CSRAM simulates the effect of risk factors on activity durations in both favorable and adverse directions, which means that greater or less than the most-likely activity durations can happen within the range from maximum to minimum. This feature aligns with the real situation encountered in projects because risks do not always affect project variables solely in the unwanted negative direction, rather the affection might occur also in the positive favorable direction. In this regard, in a practical manner, activity durations are represented by three estimated values (the minimum (optimistic), most likely, and maximum (pessimistic) durations) in CSRAM instead of using probability distributions. This feature of CSRAM provides practicality because establishing probability distributions would have required a large amount of reliable data from previous projects. Instead, CSRAM leverages the user's experience and foresight in this regard and processes the data entered by the user. Furthermore, CSRAM models the risk-factors influencing the schedule activities using input data such as "risk-factor situation probability boundaries, activity/risk-factor influence degrees and correlation information between risk-factors" as shown in the table below titled "*Data used as input to CSRAM applied to the project handled in the 'Example Application' section of the paper*". In other words, just like the activity durations, CSRAM does not require the risk factors to be represented by probability distributions. During the execution of MCS, CSRAM processes all this data to find a value for the activity duration of each activity, runs the CPM's backward and forward pass calculations, and records a different project completion time in each case of MCS iteration. At the end of the simulation, CSRAM presents the results obtained and reveals the quantitative effect of risks on the schedule.

In this regard, CSRAM determines the activity durations to be used in each CPM iteration generated by MCS to be either less than the most-likely duration, closer to the minimum expected duration, or more than the most-likely duration, closer to the maximum expected duration. This process occurs randomly based on the input data provided to CSRAM, simulating the real situation for the project schedule. Throughout this process, no probability distributions are needed or used by CSRAM, rather the CSRAM applies a practical way to capture the correlations between activities and among risk-factors, and simulate the uncertainty effect on the schedule.

Appendix I

Data used as input to the CSRAM implemented for the project handled in the "Example Application" section of the paper.

		Risk-factors, Risk-factor situation probability boundaries & Activity / Risk-factor influence degrees*									
MCS Iteration Number 1000 Correlated Risk-factors: 3 & 4		1- Design changes inside the organization of the Designer	2- Design changes requested by the Regional Office	3- Design changes requested by the Design & Construction Unit	4- Late approval of design documents by the Design & Construction Unit	5- Low productivity among the staff of Designer	6- Staff shortage within the organization of Designer	7- Bad weather conditions during the site investigation	8- Owner's delay in payment	9- Disputes with the Design & Construction Unit on technical and contractual issues	10- Delay in written communication within the Owner's organization
Risk-factor Situations	Better-than-expected	0.40	0.10	0.10	0.10	0.20	0.20	0.20	0.30	0.40	0.10
	Expected	0.80	0.90	0.20	0.20	0.50	0.80	0.60	0.70	0.80	0.50
	Worse-than-expected	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Activities & Activity Durations in days (Minimum Expected / Most likely / Maximum Expected)	Act. 1 1/1/1	IE	IE	IE	IE	IE	IE	IE	IE	E	VE
	Act. 2 20/30/35	IE	IE	IE	IE	E	IE	IE	IE	IE	IE
	Act. 3 7/10/40	IE	IE	IE	E	IE	IE	IE	IE	IE	IE
	Act. 4 60/75/90	VE	IE	IE	IE	VE	VE	VE	IE	IE	IE
	Act. 5 15/20/50	IE	IE	VE	VE	IE	IE	IE	IE	E	VE
	Act. 6 15/20/40	VE	IE	IE	IE	VE	VE	E	E	IE	IE
	Act. 7 7/10/80	IE	E	VE	VE	IE	IE	IE	IE	E	IE
	Act. 8 10/15/40	E	IE	IE	IE	VE	E	E	E	IE	IE
	Act. 9 5/5/50	IE	IE	IE	VE	IE	IE	IE	IE	E	IE
	Act. 10 20/30/50	E	IE	IE	IE	VE	VE	IE	E	IE	IE

MCS Iteration Number 1000 Correlated Risk-factors: 3 & 4		Risk-factors, Risk-factor situation probability boundaries & Activity / Risk-factor influence degrees*									
		1- Design changes inside the organization of the Designer	2- Design changes requested by the Regional Office	3- Design changes requested by the Design & Construction Unit	4- Late approval of design documents by the Design & Construction Unit	5- Low productivity among the staff of Designer	6- Staff shortage within the organization of Designer	7- Bad weather conditions during the site investigation	8- Owner's delay in payment	9- Disputes with the Design & Construction Unit on technical and contractual issues	10- Delay in written communication within the Owner's organization
Risk-factor Situations	Better-than-expected	0.40	0.10	0.10	0.10	0.20	0.20	0.20	0.30	0.40	0.10
	Expected	0.80	0.90	0.20	0.20	0.50	0.80	0.60	0.70	0.80	0.50
	Worse-than-expected	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Activities & Activity Durations in days (Minimum Expected / Most likely / Maximum Expected)	Act. 11 7/10/90	IE	E	VE	VE	IE	IE	IE	IE	E	IE
	Act. 12 50/70/100	E	IE	IE	IE	VE	VE	VE	VE	IE	IE
	Act. 13 40/60/150	IE	E	VE	VE	IE	IE	IE	IE	E	IE
	Act. 14 60/70/90	E	IE	IE	IE	VE	VE	E	E	IE	IE
	Act. 15 30/40/120	IE	E	VE	VE	IE	IE	IE	IE	E	IE
	Act. 16 7/10/20	E	IE	IE	IE	VE	E	IE	E	IE	IE
	Act. 17 5/5/40	IE	E	VE	VE	IE	IE	IE	IE	E	IE
	Act. 18 7/10/30	E	IE	IE	IE	VE	E	IE	E	IE	IE
	Act. 19 5/5/40	IE	E	VE	VE	IE	IE	IE	IE	E	IE
	Act. 20 20/30/40	E	IE	IE	IE	VE	VE	IE	E	IE	IE

		Risk-factors, Risk-factor situation probability boundaries & Activity / Risk-factor influence degrees*									
MCS Iteration Number 1000 Correlated Risk-factors: 3 & 4		1- Design changes inside the organization of the Designer	2- Design changes requested by the Regional Office	3- Design changes requested by the Design & Construction Unit	4- Late approval of design documents by the Design & Construction Unit	5- Low productivity among the staff of Designer	6- Staff shortage within the organization of Designer	7- Bad weather conditions during the site investigation	8- Owner's delay in payment	9- Disputes with the Design & Construction Unit on technical and contractual issues	10- Delay in written communication within the Owner's organization
Risk-factor Situations	Better-than-expected	0.40	0.10	0.10	0.10	0.20	0.20	0.20	0.30	0.40	0.10
	Expected	0.80	0.90	0.20	0.20	0.50	0.80	0.60	0.70	0.80	0.50
	Worse-than-expected	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Activities & Activity Durations in days (Minimum Expected / Most likely / Maximum Expected)	Act. 21 10/10/60	IE	E	VE	VE	IE	IE	IE	IE	E	IE
	Act. 22 7/10/30	E	IE	IE	IE	VE	VE	IE	E	IE	IE
	Act. 23 5/5/60	IE	E	VE	VE	IE	IE	IE	IE	E	IE
	Act. 24 3/4/20	IE	IE	IE	IE	VE	E	IE	E	IE	IE
	Act. 25 3/4/40	IE	IE	IE	VE	IE	IE	IE	IE	IE	IE
	Act. 26 3/4/10	IE	IE	IE	IE	VE	E	IE	E	IE	IE
	Act. 27 3/4/40	IE	IE	IE	VE	IE	IE	IE	IE	IE	IE
	Act. 28 3/4/10	IE	IE	IE	IE	E	E	IE	E	IE	IE
	Act. 29 3/4/40	IE	IE	IE	VE	IE	IE	IE	IE	IE	IE
	Act. 30 7/8/60	IE	IE	IE	E	IE	IE	IE	E	IE	IE

MCS Iteration Number 1000 Correlated Risk-factors: 3 & 4		Risk-factors, Risk-factor situation probability boundaries & Activity / Risk-factor influence degrees*									
		1- Design changes inside the organization of the Designer	2- Design changes requested by the Regional Office	3- Design changes requested by the Design & Construction Unit	4- Late approval of design documents by the Design & Construction Unit	5- Low productivity among the staff of Designer	6- Staff shortage within the organization of Designer	7- Bad weather conditions during the site investigation	8- Owner's delay in payment	9- Disputes with the Design & Construction Unit on technical and contractual issues	10- Delay in written communication within the Owner's organization
Risk-factor Situations	Better-than-expected	0.40	0.10	0.10	0.10	0.20	0.20	0.20	0.30	0.40	0.10
	Expected	0.80	0.90	0.20	0.20	0.50	0.80	0.60	0.70	0.80	0.50
	Worse-than-expected	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Act. 31 3/4/10	IE	IE	IE	IE	VE	E	IE	E	IE	IE
	Act. 32 3/4/60	IE	IE	IE	VE	IE	IE	IE	IE	IE	IE

*E: effective, VE: very effective, IE: ineffective

Appendix J

Results of the CPM and CSRAM applications regarding the uncertainty on activity criticality for the project handled in the "Example Application" section of the paper.

Activity No.	Total Float (CPM)	Criticality (CPM)	Minimum Total Float (CSRAM)	Maximum Total Float (CSRAM)	Criticality (CSRAM)	Uncertainty in Criticality (CSRAM)
1	0	Critical	0	0	Critical	-
2	35	Noncritical	0	45	Near-Critical	High
3	35	Noncritical	0	45	Near-Critical	High
4	0	Critical	0	0	Critical	-
5	0	Critical	0	0	Critical	-
6	0	Critical	0	0	Critical	-
7	3	Noncritical	0	21	Near-Critical	High
8	0	Critical	0	21	Near-Critical	High
9	0	Critical	0	21	Near-Critical	High
10	0	Critical	0	0	Critical	-
11	0	Critical	0	0	Critical	-
12	0	Critical	0	0	Critical	-
13	0	Critical	0	0	Critical	-
14	25	Noncritical	12	128	Noncritical	-
15	25	Noncritical	12	128	Noncritical	-
16	40	Noncritical	19	100	Noncritical	-
17	40	Noncritical	19	100	Noncritical	-
18	40	Noncritical	19	100	Noncritical	-
19	40	Noncritical	19	100	Noncritical	-
20	0	Critical	0	0	Critical	-
21	0	Critical	0	0	Critical	-
22	0	Critical	0	0	Critical	-
23	0	Critical	0	0	Critical	-
24	40	Noncritical	19	100	Noncritical	-
25	40	Noncritical	23	100	Noncritical	-
26	0	Critical	0	0	Critical	-
27	0	Critical	0	0	Critical	-
28	4	Noncritical	1	11	Near-Critical	High
29	4	Noncritical	1	11	Near-Critical	High
30	44	Noncritical	19	131	Noncritical	-
31	0	Critical	0	0	Critical	-
32	0	Critical	0	0	Critical	-