Resilient Scheduling and Construction Projects

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Resilient schedules are defined by their multidimensionality: they tend to be robust, flexible, and adaptable. Previous studies in construction scheduling have predominantly focused on the robustness aspect, which is already a complex concept. On the one hand, robustness depicts the insensitivity of objective function in the optimization model, may it be project minimization or NPV maximization, for example; on the other hand, it tends to minimize the deviations between baseline schedule and realized state.

Keywords: resilience ; baseline schedule ; uncertainty ; taxonomy ; construction project

1. Overview

Complex construction projects are developed in a dynamic environment, where uncertainty conditions have a great potential to affect project deliverables. In an attempt to efficiently deal with the negative impacts of uncertainty, resilient baseline schedules are produced to improve the probability of reaching project goals, such as respecting the due date and reaching the expected profit. Prior to introducing the resilient scheduling procedure, a taxonomy model was built to account for uncertainty sources in construction projects. Thence, a multi-objective optimization model is presented to manage the impact of uncertainty. This approach can be described as a complex trade-off analysis between three important features of a construction project: duration, stability, and profit. The result of the suggested procedure is presented in a form of a resilient baseline schedule, so the ability of a schedule to absorb uncertain perturbations is improved. The proposed optimization problem is illustrated on the example project network, along which the probabilistic simulation method was used to validate the results of the scheduling process in uncertain conditions. The proposed resilient scheduling approach leads to more accurate forecasting, so the project planning calculations are accepted with increased confidence levels.

2. Resilient Schedules

Large construction projects are characterized by their complexity in terms of organization, as they consist of hundreds of activities and require numerous resources. To successfully manage important project objectives, scheduling efforts must be applied to ensure that a project is completed within the contract requirements [1]. Schedule management concentrates on the processes that are essential to appropriately deliver critical project aspects, such as time, cost, resources, etc. [2] Scheduling methods which are used to establish reliable construction plans can be broadly classified into exact [3][4][5][6], heuristic [7][8][9], or metaheuristic approaches [10][11][12][13][14]. Current practices in the domain of construction planning and scheduling are oriented towards automatic schedule development and the application of specialized optimization techniques [15]. Although modern technologies such as BIM have already been applied to the optimization problems in the realm of construction scheduling [16][17][18][19][20][21], additional development and possible extensions are still needed to effectively automatize scheduling practices and improve both customizability and user-friendliness of emerging technologies for practical use [22][23].

As construction projects take place in a dynamic environment, they are consequently prone to the negative impacts of internal and external sources of uncertainty. Due to the fact that uncertainty has been recognized as a cause of risks that can influence the final outcome of a project [24], there is an indisputable need to manage the uncertainty which is present in almost all of the construction activities [25]. However, there is still a lack of mechanisms that would leverage state-of-the-art technologies such as BIM with the uncertainty management frameworks in complex construction projects [26]. BIM-based uncertainty management frameworks are currently emerging at the theoretical level, where the automatization and practical integration of existing frameworks with new technologies remain the main challenges thus far [27].

To diminish unfavorable impacts stemming from the construction project environment, a relevant strategy is to prepare for uncertainty from the early stages of the project life cycle. To account for uncertainty as early as in the project planning phase, a resilient scheduling approach has been developed recently [28][29][30]. Resilient scheduling is a procedure to develop the optimal baseline makespan for a project, considering the trade-off between schedule stability or robustness, and other important objectives, such as makespan minimization [29]. Moreover, additional trade-offs can be considered when defining the equilibrium state of the project, such as the limited budget of the project, expected net present value, as well as adequate risk management, among other equilibrium facets [28].

Resilient schedules are defined by their multidimensionality: they tend to be robust, flexible, and adaptable. Previous studies in construction scheduling have predominantly focused on the robustness aspect, which is already a complex concept. On the one hand, robustness depicts the insensitivity of objective function in the optimization model, may it be project minimization or NPV maximization, for example; on the other hand, it tends to minimize the deviations between baseline schedule and realized state. For instance, Zhao et al. [31] propose the framework for integrated robustness evaluation, considering composite robustness measure. Authors have been using improved subjective and objective weights in order to evaluate the schedule robustness. In another research, Zhao et al. [32] investigated the importance of schedule robustness by use of metaheuristic optimization techniques, considering both activities' starting-time deviation, as well as a structural deviation in a schedule.

On the other hand, information about the uncertainty in a construction project is usually scattered, as it arises from various sources, and due to the dynamics of complex construction projects, it is extremely demanding to organize, collect, and reuse that knowledge. Lack of information or ambiguous data can have undesirable consequences on project success and cause a negative impact to project objectives. According to Reference [33], significant efforts have been undertaken to consider more general sources of uncertainty in the project management domain. Because of the inherent complexity in large construction projects, there is a need to manage a considerable amount of information [34].

In the realm of construction management, different researchers have attempted to integrate knowledge about uncertainty into formal conceptualization. This way, domain knowledge can be accessed and reused by users in a form of computer-readable data [35]. For example, Tah and Carr [36] proposed a knowledge-based approach to facilitate effective risk management procedures in a construction project. Ping Tserng et al. [37] developed an ontology-based risk management framework to improve the overall effectiveness of risk management practices for a construction contractor. The study of Ding et al. [38] coupled ontology and semantic web technology in a BIM environment to manage construction risk knowledge. Apart from enhancing general risk management procedures, other practical applications of ontology in the construction domain include knowledge sharing [39][40][41], information extraction [42][43][44], and performance analysis [45][46][47][48].

So far, however, there has been little discussion about modeling a comprehensive knowledge base by considering general sources of uncertainty in construction projects. Therefore, the first aim of this research was to structure uncertainty sources related to complex construction projects in a faceted taxonomy, as a basis for the analysis and uncertainty management in construction projects from the early planning stages. Comprehensive identification and characterization of uncertainties in the construction domain is a first step towards increasing the probability of reaching project goals during the execution phase.

Considering the nature of complex construction projects, which are financially extremely demanding undertakings, appropriate cash procurement is of vital importance. The major source of financing for construction projects is the establishment of the bank overdraft [49][50]. If the cash deficit occurs during the project realization period, contractors will encounter difficulties related to the implementation of the project activities in accordance with a baseline plan [51]. Therefore, the development of a schedule where the cash flows will be suitable for the established bank overdraft is an important subject, since large construction projects require extensive investments and rarely depend solely on the savings of the contractor [49][50].

3. Conclusions

Validation results suggest that resilience of a baseline solution improves with SM value maximization. However, the scope of the research was limited to a small project network, so caution must be applied when examining larger problem instances, since the findings might not be unconditionally transferable to a construction projects based on the more complex precedence networks. Although the research has laid the theoretical foundations for resilient scheduling procedure, the study has certain limitations. For example, the resilience framework should be tested on a larger set of project data collected from real construction projects to analyze the systems' behavior. Moreover, further research might explore different surrogate measures to interpret the resilience capacity of the baseline schedules for various types of construction projects. Finally, the development of new metaheuristic algorithms will enable detailed analysis and validation of the proposed resilience framework on a larger set of problems.

The present research introduces the financing aspect into the process of resilient scheduling, so the comprehensiveness and feasibility of the initial schedule are significantly improved. The advantage of the proposed resilient project planning is enhanced stability of the baseline schedule in comparison with the simulated state of project execution. This leads to more accurate forecasting, so the project-planning calculations are accepted with higher confidence levels.

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