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Evaluation of Expansion of Managerial Flexibilities of Critical Path Method Scheduling Under Uncertainty Through A Risk Simulation Model

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Abstract

Scheduling of a construction project using an activity network can be done using the Critical Path Method (CPM). CPM scheduling, since it was first developed in the USA in 1950's, has been widely applied in various sectors including the construction sector. CPM, however, is incapable of reflecting the influence of uncertainty on schedules and modelling the stochastic character of projects' real-life conditions. In order to achieve success in complex, uncertain, and dynamic conditions, today's construction projects do show a need for methods that are more flexible from a managerial point of view. Therefore, this study investigates the expansion of managerial flexibilities of CPM scheduling in case it would be integrated with Monte Carlo Simulation (MCS) through a schedule risk analysis method called the Correlated Schedule Risk Analysis Model (CSRAM). For this purpose, firstly, the subject is discussed conceptually, and next an example application on a project is introduced to illustrate the potential of CSRAM in terms of flexibility. The flexibilities have been investigated at three levels, i.e. activity, path and project level. The results have revealed that it seems possible to expand the managerial flexibilities inherently present in CPM, in case risk analysis capability is incorporated. However, the level of expansion of managerial flexibilities could change in adverse or favourable direction depending on various factors such as the project phase, project size, project conditions, contract terms, and stakeholder requirements. These factors could be subject of further research. Other scheduling methods used in construction projects such as the Critical Chain Method, Line of Balance and Linear Scheduling Method could be investigated in the same manner to go one step further on the way towards more flexible project management in construction from the scheduling viewpoint.

Keywords: *Critical Path Method, Monte Carlo Simulation, flexible project management, managerial flexibility, schedule risk analysis.*

1 Introduction

Construction projects are required to be completed in planned time, cost and scope along with ensuring the stakeholder satisfaction in terms of quality, functionality, safety and environmental issues. Scheduling of a construction project in which the project activities can be combined with each other in the form of an activity network can be done by using the Critical Path Method (CPM) (Newitt, 2009; Oberlender, 2014). Thanks to the information the CPM schedules provide to track duration, budget and resources, CPM scheduling is utilised to keep control primarily on the time - cost - scope triad of this multidimensional problem. In spite of its superiorities as a project scheduling method, CPM also has a distinct shortcoming. It is not capable of reflecting the influence of uncertainty on the schedules due to its rigid deterministic nature (Ammar, 2013; Jaafari, 1984; Koskela et al. 2014; Ökmen and Öztaş, 2008, Zhou et al., 2013). Actually, all the information generated by CPM is prone to variation due to various risk-factors affecting the projects. Project completion time, activity/path criticalities, activity float times, and early/late start/finish activity times obtained by CPM are prone to variation during the implementation of a project.

In order to overcome this shortcoming, many studies have been conducted. In most of these studies, risk analysis capability is added to CPM by using the probability and statistics, fuzzy set theory or simulation techniques (Woolery and Crandall, 1983; Ahuja and Nandakumar, 1985; Pohl and Chapman, 1987; Wang and Demsetz, 2000; Öztaş and Ökmen, 2005; Ökmen and Öztaş, 2008; Ökmen and Öztaş, 2014). These studies tried to improve CPM in compliance with the uncertain, complex and dynamic features of construction projects. However, none investigated the potential for expansion of managerial flexibilities of the CPM scheduling in case its aforementioned extensions are applied. In order to achieve success under complex, dynamic and uncertain project conditions, today's construction projects have a need for more flexible methods and tools. Therefore this study aims to investigate the expansion in the managerial flexibilities of CPM scheduling in case it is integrated with Monte Carlo Simulation (MCS) for the purpose of converting it into a schedule risk analysis tool.

Firstly, in Section 2, literature is investigated to bring an explanation to the 'flexibility' concept in project management and how flexibility can be linked to different characteristics of traditional CPM. Next, in Section 3, a previously developed MCS based CPM simulation method called the Correlated Schedule Risk Analysis Model (CSRAM) (Ökmen and Öztaş, 2008) is briefly introduced and how the flexibility capacity of CPM would be improved through this model is discussed conceptually. Subsequently, in Section 4, an example application of CSRAM on a project is presented in order to show the expansion of managerial flexibilities of CPM scheduling under uncertainty. Besides, the results are discussed within Section 4. Conclusions are drawn and recommendations for further research are introduced in Section 5.

2 Managerial Flexibilities of CPM

The literature on project management brings a number of different definitions for 'flexibility' such as the capability and preparedness of coping with the dynamics of a project (Jalali-Sohi et al., 2019) and uncommitted potential towards change (Bateson, 1972). Taking into account these definitions, 'flexibility' in projects can be considered as the adaptability of a project to complex, uncertain and dynamic conditions. A paradigm change in traditional project management seems needed for gaining flexibility and adaptability for change. One of the ways to gain flexibility is to develop new project management methodologies inspired by modern project management approaches such as lean and agile on the macro scale (Fernandez and Fernandez, 2008; Jalali et al., 2015; Agile Manifesto, 2020). At the micro-scale, flexibility could be gained by exploring the managerial flexibilities inherent with the existing methods such as the MCS based CPM models. This study reports an effort on the micro-scale side of the abovementioned context. This section firstly discusses the managerial flexibilities inherent with the traditional CPM scheduling in order to open the way to explore the flexibilities provided by its extensions such as the CSRAM. The flexible features of the CPM from the management point of view are briefly explained in this section at three levels in line with the information it provides, i.e. activity, path, and project levels. A broader discussion on the managerial flexibilities inherent with the CPM scheduling can be found in Ökmen et al. (2020).

Activity-level flexibility is associated with the floats or float times of the noncritical activities in a CPM activity network. The floats can be categorised as total, free, shared and independent. The float time of an activity represents the flexibility associated with that activity in terms of the time interval for which the execution of this activity can be skipped or extended without causing any delay on the project completion time as well as on the early start times of the successors of that activity. *Path-level flexibility* is associated with the float times of the noncritical paths in a CPM activity network. Noncritical paths possess float times due to the noncritical activities lying on these paths. Accordingly, the float of a path could be consumed in agreement with the float times and float categories of the noncritical activities on that path. *Project-level flexibility* is associated with the various capabilities of CPM including, but not limited to, resource levelling, resource transferring, project compression (schedule crashing and fast-tracking), time-cost trade-off analysis (optimization), delay analysis, float allocation, dispute resolution, schedule risk analysis, what-if analysis, updateability via CPM based scheduling software, and monitoring and control through techniques like Earned Value Method and S-Curve analysis (Newitt, 2009: Oberlender, 2014; Del Pico, 2013).

To allow for more flexibility, several scholars have developed extensions of CPM, such as Woolery and Crandall (1983), Ahuja and Nandakumar (1985), Wang and Demsetz (2000), Öztaş and Ökmen (2005), and Ökmen and Öztaş (2014). One of these extensions is CSRAM, as reported in Ökmen and Öztaş (2008). CSRAM is able to indirectly and qualitatively capture the correlations between activities and between risk-factors concurrently. This feature converts CSRAM into an effective schedule risk analysis method to model the complex and uncertain conditions of construction projects realistically. The correlations between activities and between risk-factors are shown as one of the drivers of complexity in construction projects (Xua et al., 2018). Hence for the purpose of evaluating the expansion of flexibilities of CPM scheduling under uncertainty, CSRAM has been used in this study to model the uncertain project conditions without ignoring the correlations between activities and risk-factors.

3 Expansion of Managerial Flexibilities of CPM through CSRAM

CSRAM was developed as a schedule risk analysis method to be utilised in the risk management processes of construction projects (Ökmen and Öztaş, 2008). The method was built upon the integration of MCS with CPM. MCS is a simulation technique, which is used to carry out quantitative risk analysis on projects by means of spreadsheet software specifically developed for this purpose such as @Risk® and Crystal Ball®. MCS enables to model different aspects of projects such as cost estimations and time schedules by simulating the real life conditions in a stochastic way through this software, which otherwise would be almost impossible to do analytically. MCS produces random variables in agreement with the statistical characteristics of the input data by the help of the algorithms embedded within CSRAM. At the end of each MCS run containing a sufficiently high number of successive CPM applications, a series of statistical data is obtained regarding the variations on different project aspects, which might happen during the project execution due to uncertainty.

MCS was integrated into CPM in order to gain the capability of simulating the uncertain conditions of real life through running the CPM as many times as needed by randomly produced data, for example tens of thousands times or even more. Each CPM run generated through MCS within CSRAM represents a different story for the project based on the CPM. In other words, risk-factors that are assumed to affect a project follow a different impact trend in each CPM run during the simulation. The data used in each CPM run is selected randomly by the CSRAM through taking the possible correlations between activities and between risk-factors (‘two-sided’ correlations) into account. In this process, qualitative data is utilised, which is entered to the CSRAM to enable it to capture these correlations indirectly, i.e. without directly requesting correlation coefficients. Such ‘two-sided’ correlations may amplify the intensity of uncertainty on CPM schedules. Therefore, neglecting the correlations between activities and risk-factors would lead to inaccurate results in case of analysing the effects of uncertainty on a CPM schedule. In accordance, CSRAM has been loaded with the ability to model the two-sided correlation effect in question. As mentioned above, the model utilises the qualitative data entered in order to randomly select the activity durations that will be used in each CPM run. Since CSRAM is a stochastic extension of CPM, the activity durations are identified to CSRAM in the form of three duration estimations, i.e. most likely, minimum (optimistic) and maximum (pessimistic), instead of single duration estimates as in the case of CPM, so that CSRAM selects the activity durations randomly from the time intervals constituted in between these estimated three duration values in agreement with the risk and correlation information provided to the model.

Activity-level flexibility of CSRAM is mainly associated with the variation in float times and float types of the activities. Unlike the traditional CPM, CSRAM reveals the frequency or probability of being critical or noncritical for each activity throughout a simulation. In other words, the activities do not necessarily become either critical or noncritical in CSRAM, rather they follow critical, noncritical or near-critical behaviour depending on the low or high total float variability. This situation creates an expansion in terms of managerial flexibility in the sense that it becomes possible to detect which activities are more prone to risk-factors by analysing their frequencies of being critical, noncritical or near-critical and by evaluating the variability in their total float times. In more clear terms, the flexibility of being aware of the variation in activity float times would support the decision-making processes on how to use the total, free, shared and independent floats in the best way during the management of a schedule.

Path-level flexibility of CSRAM is associated with the variation in float times of the noncritical paths. Unlike the traditional CPM, CSRAM discloses the frequency or probability of being critical or noncritical for each path during a simulation. In other words, the paths are not necessarily critical or noncritical in CSRAM, rather they have probabilities of occurring as critical, noncritical or near-critical. Besides, CSRAM enables the detection of the risk-factors that are more effective on each path through sensitivity analysis. All this information is considered to expand the managerial flexibility at the path-level by supporting the decision-making processes associated with the activity paths of a schedule.

Project-level flexibility of CSRAM can be evaluated under two different headings. Firstly, CSRAM provides the flexibility of evaluating the impact of uncertainty on the project duration. In other words, contrary to traditional CPM, CSRAM is capable of showing the variation on the possible shortest project completion time in advance. Being aware of the possibilities on how much time the project will take and getting the opportunity of building the management strategies on such information rather than sticking to a single project duration forecast as in the case of traditional CPM can be considered as a flexibility expansion from the management point of view. Secondly, the flexibility of CSRAM at project-level is associated with the enrichment of the existing capabilities of CPM such as resource transferring, resource levelling, schedule crashing, and schedule updating by the information provided associated with the variation in criticalities, float times and float types of the activities caused due to risk-factors.

The next section introduces an example application on a project to show how the managerial flexibilities expand in practice compared to traditional CPM when CPM is implemented through CSRAM for the sake of taking the effect of uncertainty and correlation in schedules into account.

4 An Example Application

The project handled in the example application is the construction job of a production plant on behalf of a client through a turnkey contract, i.e. the contractor takes the full responsibility of design, procurement and construction and delivers the fully completed facility to the client in the end. Furthermore, the payment system in the contract is a cost-plus-fixed fee with guaranteed maximum cost and the contract contains terms that allow bonus payment to the contractor if the project is completed earlier than the contractually negotiated duration. However, the contract also proposes the execution of a financial penalty in case of a non-excusable delay in the delivery of the project. The contractor envisages the activity network information to be used for preparing the CPM schedule of the project as shown in Table 1. The activity durations on this table are the estimated values for most-likely (expected) durations. The data in Table 1 is not only used in the execution of traditional CPM but also during CSRAM application, as CPM is implemented repetitively and many times through MCS in CSRAM.

Firstly, the CPM and CSRAM applications assumed to be conducted by the contractor before signing the contract are introduced. Next, it is described how the results obtained at this stage would affect the decisions taken by the contractor. Finally, the results in terms of the managerial flexibilities obtained by the CPM and CSRAM applications and how these flexibilities can be utilized by the contractor are compared and discussed.

4.1 CPM Application

The time schedule of the project was prepared by the contractor through the CPM's forward/backward pass calculations (Newitt, 2009; Oberlender, 2014). The main points on this schedule are the activities A, B, F, H, I, and J, the critical activities having no float times, the activities C, D, E, and G, the noncritical activities having float times, the Path 1 (A–B–C–D–E–H–I–J) and Path 3 (A–B–G–I–J) are the noncritical paths, the Path 2 (A–B–F–H–I–J) is the critical path, and the shortest possible project duration is 120 days.

The total, free, shared, and independent float times of the activities, float sharing activities, float times of the paths, and the criticalities of the activities and the paths are given in Table 2. The contractor estimated the activity durations used in the CPM application based on his/her previous experience and in compliance with the available resources. Accordingly, the shortest possible project duration, which is 120 days and other values and information given in Table 2 are all deterministic and assumed to have not varied through risk-factors that may affect the project. Therefore, the contractor appealed to CSRAM before negotiating the details of the contract in terms of project completion (delivery) time, risk allocations and float usage entitlements, which would indirectly affect the managerial flexibilities.

Table 1. Activity network information used in CPM application on the example project.

Activity Label	Activity Description	Activity Duration (day)	Predecessor Activity	Network Relationship
A	Start / Site Takeover	1	-	-
B	Design & Owner's Approval	30	A	Finish-to-Start
C	Prefabrication / Formwork	7	B	Finish-to-Start
D	Prefabrication / Reinforcement	7	C	Finish-to-Start
E	Prefabrication / Concrete	20	D	Finish-to-Start
F	Excavation & Foundation	40	B	Finish-to-Start
G	Machinery / Production & Transfer	65	B	Finish-to-Start
H	Prefabricated Units / Transfer & Montage	30	E & F	Finish-to-Start
I	Machinery / Montage & Testing	14	H & G	Finish-to-Start
J	Finish / Project Delivery	5	I	Finish-to-Start

Table 2. Results of CPM application on the example project.

Activity/ Path No.	Free Float Time*	Shared Float Time	Independent Float Time	Total Float Time	Float Sharing Activity	Path Float Time	Criticality
A	0	0	0	0	-	N/A	Critical
B	0	0	0	0	-	N/A	Critical
C	0	6	0	6	D & E	N/A	Noncritical
D	0	6	0	6	C & E	N/A	Noncritical
E	6	6	0	6	C & D	N/A	Noncritical
F	0	0	0	0	-	N/A	Critical
G	5	0	5	5	-	N/A	Noncritical
H	0	0	0	0	-	N/A	Critical
I	0	0	0	0	-	N/A	Critical
J	0	0	0	0	-		Critical
Path 1	N/A	N/A	N/A	N/A	N/A	6	Noncritical
Path 2	N/A	N/A	N/A	N/A	N/A	0	Critical
Path 3	N/A	N/A	N/A	N/A	N/A	5	Noncritical

*All time values are given in "days".

4.2 CSRAM Application

The activity durations used in CPM application were accepted as the most-likely durations in CSRAM application. Besides, the minimum (optimistic) and maximum (pessimistic) activity durations were estimated based on the experiences gained from previous similar projects along with holistically considering various uncertainty creating risk factors. Next, the activity durations were represented by using these three time estimations. The network and predecessor relationships between the activities used in CPM application given in Table 1 were used also in CSRAM application. Furthermore, based on previous experience and engineering judgment, major risk-factors that might affect the schedule were determined along with their individual influence degrees in the form of effective (E), very effective (VE) and ineffective (IE) qualitative terms, and risk-factor situation probability boundary values in the form of better-than-expected, expected and worse-than-expected quantitative terms (refer to Ökmen and Öztaş, 2008). The iteration number for the MCS was selected with a value of 10000. The contractor estimated by experience that the risk-factors 2 and 10, and 4 and 5 have positive correlations between them as shown in Table 3. Accordingly, the correlation between risk-factors has been defined to CSRAM in line with this prediction. Table 3 presents the CSRAM results regarding the project duration uncertainty and project/risk- factor sensitivity. The sensitivity of the project to the risk-factors has been ranked according to the coefficient of variation values (i.e. the ratio of standard deviation to the mean) obtained by executing the CSRAM with turning on the risk-factor queried in each case and neglecting the other risk-factors. CSRAM also provided data regarding the uncertainty in floats and criticalities, and path float uncertainty and path/risk-factor sensitivity, which could not be included into the paper due to size limitation.

Table 3. Results of CSRAM application on the example project.

Scenario	Minimum Project Duration (day)	Mean Project Duration (day)	Maximum Project Duration (day)	Standard Deviation of Project Duration	Coefficient of Variation	Sensitivity Rank
All Risk-Factors	103,86	135,33	181,58	12,28	0,09	-
Risk-Factor 1 (Design changes)	116,09	121,22	128,46	2,87	0,02	3
Risk-Factors 2 ~ 10 (Correlated) (Delays caused by Owner ~ Disputes with Owner	111,82	125,59	144,23	8,16	0,06	1
Risk-Factor 3 (Underground soil conditions)	116,50	120,01	122,33	1,16	0,01	4
Risk-Factors 4 ~ 5 (Correlated) (Weather conditions ~ Labor productivity on construction site)	113,20	125,18	139,20	6,90	0,06	1
Risk-Factor 6 (Labor productivity during prefabrication)	120,00	121,20	132,19	2,90	0,02	3
Risk-Factor 7 (Delays caused by Supplier)	119,70	120,70	124,37	1,18	0,01	4
Risk-Factor 8 (Design & assembly faults on construction site)	116,93	121,98	132,27	4,09	0,03	2
Risk-Factor 9 (Malfunctioning of machinery during testing)	118,60	120,75	128,76	2,27	0,02	3

4.3 Discussion of the Results

In this section, the managerial flexibilities obtained through the CSRAM and CPM applications are compared and discussed from the contractor's perspective. Before signing the contract, the contractor has to negotiate with the client about how long after the start the project must be completed. The project completion time found by applying CPM, which is 120 days, is quite misleading for the contractor because this value is calculated without taking into account the project risks. In case the project delivery time would be agreed to 120 days in the contract, the contractor might face penalties during construction in case of occurrence of delays. Besides, managing the project by benefitting from the flexibilities provided by CPM in terms of activity and path float times would also mislead the contractor as these values may deviate from the estimated values and leads to a misleading sense of flexibility in terms of float usage and resource levelling. Since the contract is a turnkey cost-plus-fixed fee with guaranteed maximum cost type of contract, any ceiling amount for the project cost determined based on the 120 days of project duration may not only cause delay penalties but also may lead to a loss in the fixed fee that the contractor will be paid in the end because of overrunning the maximum guaranteed cost written in the contract.

In our study, it has been observed that the whole picture obtained by CSRAM is highly complicated and non-deterministic compared to the picture obtained through the CPM application. The CSRAM application, however, provided various flexibilities at activity, path and project levels ready to be benefitted:

- Flexibilities at project level: If the contractor comes to an agreement with the client regarding the project completion time to be 120 days, he/she has only 9.92% chance of completing the project within this duration, which is a low probability value. Thanks to the results obtained by CSRAM, the contractor has a flexibility in terms of decision-making to envisage the project completion time before signing the contract. The project duration may vary from minimum approximately 104 days up to maximum approximately 182 days with a mean value of 135 days as given in Table 3. The contractor has now the opportunity of determining a project duration based on the risk balance between time and cost, in order to avoid a possible overrunning of the maximum guaranteed cost. The contractor may also get the chance of taking the bonus by completing the project before the negotiated contractual date. At this point, no need to say the duration proposed by the contractor during the negotiations before signing the contract would definitely be greater than 120 days, which the CPM proposes and most probably between 135 days and 182 days. The flexibility of this kind, which can be categorised as a project-level flexibility, empowers the decision-making capability of the contractor before signing the contract and also the managing capability during the construction associated with the increased probability of completing the project within the scheduled time. The results in Table 3 related to the project duration uncertainty and project/risk- factor sensitivity have shown that the minimum, maximum, mean and standard deviation of project duration have changed in each sensitivity analysis. The coefficient of variation has disclosed the relative influence of the risk-factors on the project duration. As shown in Table 3, the most effective risk-factors on the schedule are the correlated risk-factors 2 and 10 ("Delays caused by Owner" and "Disputes with Owner"), the correlated risk-factors 4 and 5 ("Weather conditions" and "Labor productivity on construction site"), and the risk-factor 8 ("Design & assembly faults on construction site"), respectively. Now, the contractor would be aware of the most influencive risk-factors on the project duration, which provides him/her flexibility in decision making. This is a critical information during the pre-contracting stage and also important during the construction for controlling the processes related to these risk-factors with caution.

- Flexibilities at activity and path levels: All of the activities and paths may become critical during construction. Some of the activities have a high level of uncertainty in terms of criticality, i.e. near-critical, while some of them are always critical without doubt when the difference between the maximum and minimum total float times are taken into account. A similar situation exists also for the paths. The varied path float times calculated by the CSRAM show that each path has a chance of being critical, near-critical or noncritical. Furthermore, uncertainty in other float types, i.e. free, shared and independent, have also been captured. What does this information mean from the flexibility perspective? The difference between the float times obtained with respect to the project duration that would be negotiated between the client and contractor along with the target project duration that the contractor aims to complete the project to get the bonus payment will constitute an additional flexibility that can be benefitted by the contractor. For instance, if the client and the contractor come to an agreement on the 150 days of project completion time and the contractor is aware that it is also possible to finish the project within 120 days (the duration calculated through CPM application) on the condition that the project is managed by adopting the appropriate risk response strategies in compliance with the results of CSRAM application, the contractor would have more managerial flexibilities than expected. Obviously, the solution obtained by the CPM application represents only a single cross-section or situation among the other possible CPM cases. However, managing the activity and path floats in line with being aware of the all-possible cross-sections thanks to the CSRAM would create an expansion of managerial flexibilities besides getting the opportunity of taking the required risk mitigation measures. CSRAM measures the risk-factor sensitivity not only at project-level but also at path-level. In a CPM schedule, floats should not be considered only belonging to activities, rather they also belong to paths. In other words, there is a strong relationship between the activity and path floats. The contractual project duration will determine the path floats that the contractor will be able to consume. However, being aware of the minimum and maximum possible float values that may occur for each path in addition to the risk sensitivities would increase the managerial flexibilities of the contractor during the construction phase in terms of resource levelling, schedule crashing and resource transferring, which can be utilized through the path float times.

The results of this study have revealed that CSRAM, as an advanced extension of CPM when compared to the other probabilistic planning methods such as the Program Evaluation and Review Technique, could provide further managerial flexibilities in addition to the flexibilities inherent with the CPM (Ökmen et al., 2020). Also, CSRAM provides benefits through modeling the stochastic character of projects more realistically from the scheduling perspective, based on two-sided correlations between activities and risk-factors in a qualitative and quantitative way (Ökmen and Öztaş, 2008). Instead of solely sticking to the usage of CPM scheduling and the deterministic information it provides, such expanded flexibilities could be utilised through the application of CSRAM in construction projects.

5 Conclusions

Flexible project management is one of the recent approaches suggested as a response to the challenging transformation of projects becoming more complex, dynamic and uncertain. Possible responses such as flexibility and adaptability (agility), however, could not be provided by completely rejecting the traditional methods of project management. Rather, through investigating the flexibilities and adaptabilities already existing in those methodologies. Firstly, an awareness was created over the potential flexibility. In this regard, this paper aimed to disclose the expansion of flexibilities inherent in a traditional method of scheduling of construction projects under uncertainty, i.e. the Critical Path Method (CPM). In order to achieve this, a previously developed risk simulation method that is based on CPM, the Correlated Schedule Risk Analysis Model (CSRAM), has been utilised. The subject is discussed first conceptually and then illustrated through an example application on a project. The results have been compared and the expansion of managerial flexibilities in CPM in case it is applied in the form of CSRAM has been disclosed. The flexibilities have been investigated at three levels, i.e. activity, path and project, compatible with the general features of CPM networks. Although the example application was based on a simplified project containing specific contract conditions, the findings were supporting the conceptual arguments. However, the level of expansion of managerial flexibilities could change in adverse or favourable direction depending on various factors such as the project size, project conditions, contract terms, stakeholder requirements, and the project stage at which the analysis is carried out. Therefore, the subject is open to further investigation moving from this point. Besides, other scheduling methods used in construction projects such as the Critical Chain Method, Line of Balance and Linear Scheduling Method could be investigated to go one step further on the way towards more flexible project management in construction from a scheduling point of view.

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