

Exploring constraints in projects: A construction industry case study

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Abstract

Theory of Constraints (TOC) suggests managing a system according to its constraints. Critical Chain Project Management (CCPM), as an application of TOC to project management, defines a project as a chain of activities with duration as its core constraint. However, the project success literature implies that projects have different characteristics and require different approaches. This study is part of broader research that attempts to re-examine CCPM assumptions and identify constraints in different types of projects. This paper presents a case study from the construction industry. Multiple semi-structured interviews and project documents have been used as sources of data. TOC Thinking Process logic tools were used to identify the core constraint. Further investigations are made to examine other CCPM assumptions in the context of the case. CCPM assumes that projects are plagued by uncertainty, that task times are overestimated as an attempt to avoid the undesirable effects of such uncertainty (including project lateness), but that such added safety time is actually wasted. These issues, assumed by CCPM to exist, were found to exist in this case project. The CCPM's solution requires the establishment of centralized priorities for the project and elimination of deterministic start dates. These requirements were found to be challenging in the case project.

Key words: Construction, Critical Chain Project Management, Theory of constraints, thinking process tools.

Introduction

Projects are goal oriented undertakings. Project management primarily attempts to establish a process of achieving goals. Therefore, the use of prescriptive theories is essential (Ahlemann, El Arbi, Kaiser, & Heck, 2012). Theory of Constraints (TOC) has proven its capacity to invoke prescriptive solutions and applications for a diverse range of industries (Balderstone & Mabin, 1998; Gupta & Boyd, 2008; Mabin & Balderstone, 2003; Watson, Blackstone, & Gardiner, 2007) . TOC frames this research study, because of its influence on the way the researcher is actively looking to find the constraints of the

system, assuming such constraints exist. Within TOC, constraints are defined as anything that limits a system from attaining higher performance towards its goal.

TOC has been applied to project management, in order to address the typical issues experienced by project managers that led to project delays and failures (Pittman, 1994). The resulting approach, described by Goldratt (1997) as the 'Critical Chain' method for project management, challenges the flawed assumption that the only way to achieve better performance is through good local performance throughout the system. Thus, he proposed CCPM as a systemic approach which advocated focusing on the longest chain of activities. CCPM seeks to change project team behaviour: encourages reporting early completion of activities and elimination of multitasking. The early literature on CCPM emphasizes issues such as excessive activity duration, failure to pass on positive variation, and delays caused by merging, multitasking, and loss of focus. According to Leach (1999), Goldratt's TOC analysis showed that these are all effects of a core underlying cause: failure to manage uncertainty. Therefore, CCPM, as an application of TOC to project management, defines a project as a chain of activities with duration as its core constraint.

There are many published papers on empirical examples of successful applications of CCPM in the literature (Bevilacqua, Ciarapica, & Giacchetta, 2009; Hwang, Chang, & Li, 2010; Leach, 1999; Newbold, 2008; Paseuth, 2003; Realization Technologies, Inc, 2010; Smith, 2012; Stratton, 1998; Umble & Umble, 2000; Viljoen, 1997). Despite the record of its application across industry, CCPM has been criticized for its lack of applicability to a wide range of projects (Mckay & Morton, 1998; Raz et al., 2003). According to Goldratt (2009, p. 336) "an application makes assumptions (sometimes hidden assumptions) about the environment and we should not expect the application to work in environments for which its assumptions are not valid." Therefore, the assumptions underpinning CCPM need to be supported by evidence within the environment in which it is applied if such application is to be successful.

The major assumption of CCPM concerns the definition of the core constraint. As stated above, CCPM suggests the longest chain of activities is the core constraint in all projects. CCPM also assumes that certain behaviours will occur, such as deliberate padding (padding the estimates in order to avoid being late on commitments); Murphy's Law (if anything can go wrong, it will); Parkinson's Law (work extends to fill the time allowed); and student syndrome (the type of procrastination students are prone to when they are assigned a project or are facing a test) (Goldratt, 1997; Leach, 1999; Newbold, 1998). CCPM also suggests that uncertainty is the major obstacle and the core cause of undesirable effects in projects. However, Raz et al. (2003) argue that other obstacles, such as external pressure, internal policies, and distorting estimates, are as important. This paper is a part of a broader study that seeks to examine underpinning assumptions of CCPM in various types of projects.

We contend that evidence of the applicability or lack of applicability of CCPM assumptions depends on the context. This is because projects demonstrate fundamental differences in the type of challenges they face. Several empirical studies indicate that applicability of different methods and approaches is not a universal phenomenon

phenomenon (Dvir, Lipovetsky, Shenhar, & Tishler, 1998; Ratbe, King, & Young-Gul, 1999; Shenbar & Dvir, 2007; Shenhar, 2001). In fact, disagreements on applicability of many different project management methods stem from the fact that projects are different, and therefore confront different types of constraints.

This paper is part of a broader study that seeks to identify the constraints in various types of projects to investigate the implications that the constraints have in applicability of CCPM to this type of project. For this purpose, multiple cases have been studied. The purpose of the broader research project is to:

1. Re-examine the assumptions behind CCPM
2. Assess whether these assumptions hold in a range of case projects
3. Explore the connection between these assumptions and characteristics of the project.

This information will be used in order to develop a constraint-oriented classification model for projects. This paper discusses the findings from one of those cases.

Research questions pertaining to each case are as follows:

- What is the core constraint of this project?
- Is this constraint related to specific characteristics of the project?
- Do CCPM's assumptions on human behaviour manifest themselves in this project?
- What are the challenges in implementing CCPM in this project?

Methodology

This case study involved multiple semi-structured interviews with the project manager and site manager in a construction project. Project documents including project plan and risk register were also used for analysis. In addition, a visit to the site allowed a better understanding of the context and thereby contributed to the triangulation of data.

Data was analysed using two of TOC thinking processes: the Goal Tree and Current Reality Tree. The case analysis began by constructing a Goal Tree. A Goal Tree is a graphical, hierarchical representation of a system giving its goal, critical success factors and necessary conditions (Dettmer, 2011). A system is supposed to deliver a goal. Critical success factors are three to five criteria that must be achieved to realise the goal. Information from interviews and project documents was used to identify the goal, success criteria, and necessary conditions in this project. The Goal Tree was then presented to the project manager for further clarification and modification. This process was expected to confirm that the Goal Tree represented the intention of the project as it was perceived by the project manager and his team.

To clarify the core constraints which prevent the system from achieving the goal identified in the Goal Tree, a Current Reality Tree is developed. The Current Reality Tree is a tree

diagram that employs cause-and-effect logic to identify the constraint (Cox, 2003; Goldratt, 1994; Kim, Mabin, & Davies, 2008; Mabin, 1999; Scheinkopf, 1999). The Current Reality Tree depicts the state of reality as it currently exists and demonstrates the most likely chain of cause and effect between root cause and the problem or undesirable effects. The Current Reality Tree has the ability to portray complex interactions. Undesirable effects (UDE) represent the deviation between the desirable outcome, as depicted in the Goal Tree, and reality.

The TOC thinking processes also have a mechanism for verifying the validity of cause and effect logic trees through eight specific tests called the Categories of Legitimate Reservation (Dettmer, 2007). These tests guide the researcher to check that the cause and effect entities and relationships exist, and that they clearly and adequately describe the situation.

Introduction to the case

The case project was a construction project which aimed at seismic strengthening of an existing building in anticipation of future seismic activity. The building consisted of 15 levels and was located in Wellington City, which is an earthquake prone city. Prior to the project, a detailed seismic assessment had been conducted. The assessment result, indicated the building's seismic performance to be approximately 70% of the New Building Standard (% NBS) in terms of the expected performance for life safety in a 1-in-500 year earthquake. Despite the fact that the building was not classified as earthquake prone or earthquake risk in accordance with the New Zealand Society for Earthquake Engineering (NZSEE) guideline, the building owners intend to strengthen the building so that it could achieve a seismic performance of close to 100% NBS. This strengthening was perceived to increase the tenants' interest in the building for a longer term agreement, which in turn was expected to increase the potential value of the building.

The project had several stakeholders, each of whom played an important role in the project. The following section describes each stakeholder and their role.

Building owner: the building was owned by a legal entity which leased the property for profit. In addition to the rental income the value of the building was also important this is because the legal entity which owned the building intended to sell the property in the near future. This intention also impacted the project.

Consultant: The consulting company played a double role: the role of the consultant and the role of project management consultant. As the consultant, they were the advisor and communication facilitator. As the project management consultant, they were expected to manage the project. The project manager was an employee of the consulting company. His role included managing the scope, budget, programme, and risks, while also managing stakeholder expectations. He also managed the engagement and administration of all parties including design consultants and the building contractor. The consulting company also was responsible for all project documentation and reporting.

Tenants: the building was occupied by tenants. One major tenant occupied 6 levels of the building and 7 floors were occupied by 3 other tenants, while 2 levels were unaccented. The fact that the building was tenanted introduced a level of complexity. This was because contractors had to work around the constraints imposed by the nature of the tenants' businesses. For example, the tenants who occupied 6 floors were engaged in IT and used delicate networking systems. This made movements and replacements much more difficult.

Contractors: like most construction projects, multiple contractors were involved in this project. This included the fire engineering group, architects and designers, as well as the building contractor. The building contractor managed several other sub-contractors, each specializing in one area. This included carpentry, demolishing, steel work, electrical work, sprinkler installation, floor grinding work, carpet removal and replacement, and Fibre-Reinforced Plastic work. In addition, other specialists would be employed by the contractor if found to be required. For example, if the pipes were damaged, then they may need to employ plumbers to repair them.

Goal Tree

Despite the diversity of stakeholders, a set of objectives was agreed upon and signed by project actors in forms of contracts, project plan and risk management plan. This information along with interviews guided the development of the Goal Tree in this study. The Goal Tree is depicted in Figure 1, showing three critical success criteria. The following section describes each success criterion along with a list of necessary conditions as was described by the project manager or as was explained in the project management plan.

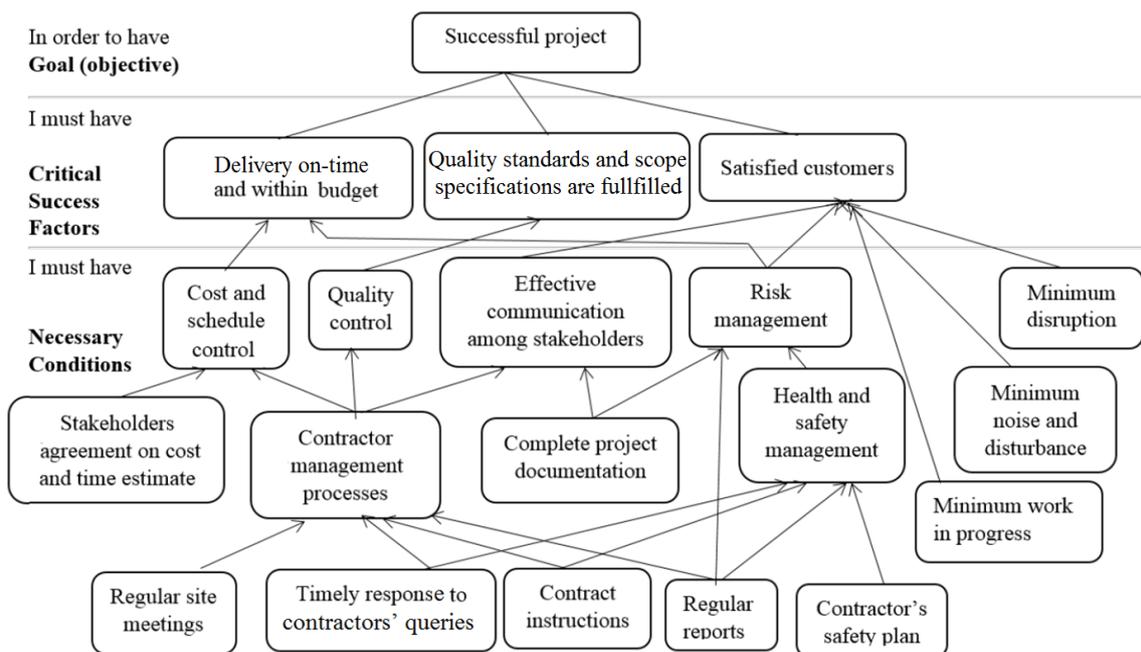


Figure 1: Goal Tree

Critical success factors: On time and within budget delivery

Projects with delays and cost overrun are not usually considered as successful projects; this project was no exception. Controlling cost and schedule requires an agreement on cost and duration estimates. Such agreement would be achieved only if all parties had enough information. The contractors and building owner decided to obtain such information by doing a trial floor which was untenanted at the time. Once all parties agreed upon cost and duration, the base line for both cost and schedule was set. The project manager then managed the contractors through channels of written communication and regular site meetings. Channels of written communications included producing documents such as contract instructions and contract query response.

Critical success factors: Quality standards

As with any other construction project, the scope of the project was defined in the design process and needed to be executed exactly as described by the designers. Despite the uncertainties in the execution process, the scope itself was well defined in advance and was not expected to change during the process. For this reason, rigorous change process documentation was in place. Confirming the delivery of scope involved the issuance of contract instructions and responding to contract queries and regular site meetings. This clearly shows that no decisions regarding the scope and quality were left to be made by the execution crew.

Critical success factors: Satisfied customer

The last, but not least, success criterion was customer satisfaction. The project manager suggested that this criterion is an important factor that would stimulate obtaining more business in the future. Customer satisfaction involved keeping the customers' customers (tenants) satisfied. This was in fact a great challenge due to the nature of the project; the project involved noise, dust, displacement, and destruction. Therefore, inconvenience for the existing tenants was inevitable; the aim was to reduce the negative effect of such inconveniences to a minimum. Thus, a great deal of customer satisfaction was expected to be achieved by reducing noise and disturbance as well as minimizing disruption.

It is important to note, that the goal of the system and necessary conditions were depicted as perceived by the project manager. Therefore, fulfilling the necessary conditions of customer satisfaction is described here from the project manager's perspective. According to the earlier citation on the role of the consultant, consultants played the middle role. The consultants therefore were the organisers of communications, and increasing effectiveness of such communications was the core in satisfying all stakeholders including their customers.

Other necessary conditions

Risk management was another necessary condition that was connected to two success criteria. The project manager reported that a risk management plan which prevents or reduces the risks, would improve customer satisfaction and prevent delays and cost overruns. The process of risk management had started with a risk brainstorming session held early in the project with the contractors. The resulting risks were recorded in the

project risk register and regularly reviewed and updated throughout the project. Construction-specific risks were assigned to be managed by the contractor. More general project-specific risks were agreed to be managed by the consultant. The risk management process during the construction phase was expected to be facilitated by the project manager. In addition, ad-hoc risk meetings, as required, were allowed to be organised by the project manager. Updates of Project Risk were included in the monthly report. As such, a well-documented risk process was found to be in place.

Three necessary conditions were identified in managing risk. Firstly, risks related to health and safety had been addressed specifically by the 'Contractor's Safety Plan'. This plan was expected to ensure that work they did, did not adversely impact on the tenants of the building or any visitors to the building. While this document was prepared and signed by all contracting companies, managing health and safety of workers was expected to be the duty of contractors for whom they worked. In addition to the Contractor's Safety Plan, further clarification was allowed by contract instructions and contract queries. Secondly, project documentation was considered to be a risk control measure. Well documented decisions were expected to reduce the impact of any forthcoming changes and also provide accurate information for future decisions. Interestingly, all risks were perceived to be managed using some form of communication.

Implications of the Goal Tree

The above Goal Tree depicts success criteria as implied by project documents and as perceived by the project manager. Elattar (2009) suggests differentiating success criteria as perceived by owner, designer, and contractor. It is interesting to note that the success criteria as described above had elements of all three, and this is because the project manager was an employee of the consulting company. In this project, the project manager was detached from both the executors of the project and the owners. And since the execution was contracted to another company, both managing time and budget were, in fact, elements of contractor management. Perhaps for the same reason, all control measures were claimed to be achievable via a communication process. In fact, the project manager indicated that contract instructions, and query responses were the key to the achievement of health and safety, controlled budget, controlled quality, and control of contractors. Similarly, he indicated that the schedule was controlled by producing and updating the Gantt chart, submitting regular reports, and conducting regular meetings, all of which are means of communication. This, it turn out, is in accordance with job dispatching theory in manufacturing. Job dispatching theory consists of deciding and communicating the assignment to the job station, and in project management the first part falls within planning and therefore the execution is reduced to mere communication (Koskela & Howell, 2002). Similarly, in this project, most necessary conditions at the bottom were means of communication.

Current reality tree

After defining the system and its goal, possible Undesirable Effects (UDE) were predicted. A summary of Current reality tree is depicted in figure 2. At core the predicted undesirable effects were triggered by wasting the excess time. While several reasons for uncertainty are beyond the span of control of the project crew, it is assumed that adding

safety time (padding) to each individual task will protect the project from delay. For this reason, padding is added to each estimate. Even though padding is meant to prevent delays due to uncertain events, it is more likely to be wasted. This is because contractors are engaging in other projects. They juggle their tasks based on predefined schedules and attempt to maximize working days of their crew. Therefore, they are unlikely to be available prior to the set dates. Wastage of this safety time leads to both delays and increased inconvenience of tenants. In particular, the convenience of tenants was emphasised as very important by the project manager. Several issues such as working hours and sequence of the floors were adjusted to reduce the inconvenience. Nevertheless, longer work in progress could seriously jeopardise customer satisfaction.

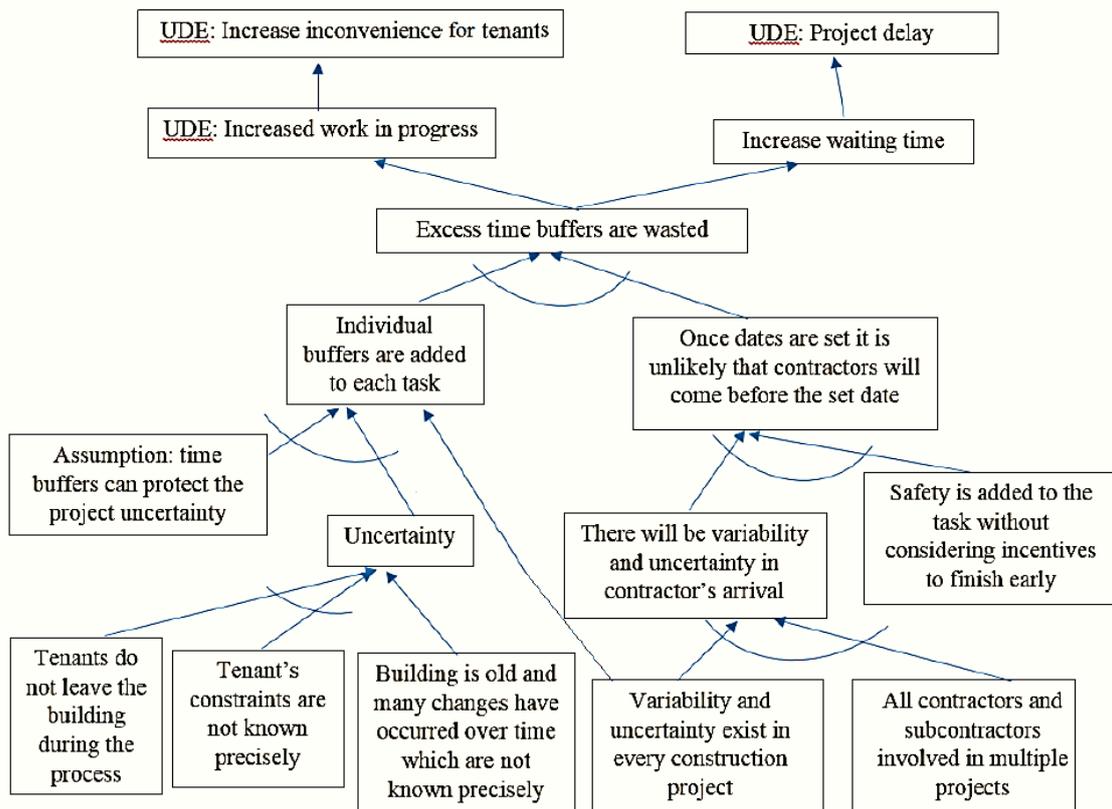


Figure 2: Current reality tree

Applicability of Critical Chain Project Management

In this section, the evidence concerning CCPM assumptions and applicability of such assumptions to this project, are discussed.

The first assumption of CCPM is that projects are controlled by a schedule. In this project arrival of each contractor was organised by the schedule. This case project also strongly supports the CCPM claims concerning overestimation of time via individual task buffer and wastage of such buffer in practice. Another assumption of CCPM, which is influenced by job dispatching theory, is division between decision makers and executors of the project, and communication as a mechanism of execution. This project clearly shows such a division exists and all execution processes are claimed to be achieved through means of communication. In essence this project does not appear to deviate much from CCPM's assumed project characteristics.

However, in order to implement CCPM one important prerequisite of CCPM is the establishment of centralized priorities. This project was executed by contractors. It was not possible to centralize the contractors' priorities. Another challenge was that with no start date, as suggested by CCPM, it was difficult to tie an array of people into a contractual agreement. While early supply of material can be accommodated to some extent early arrival of contractors is not. This is because in most cases, tasks are dependent on preceding tasks. So if they arrive early, they have to wait idle until the preceding tasks are completed. Since the contractors are only paid for the work they do, arriving early is a loss for contractors. However, arriving late may not encounter direct cost to the contractor. In fact, preventing early arrival of the contractors is maybe the motive for calculating buffers within each task.

Unity of purpose not only is an importance pre-requisite to CCPM implementation, but it prevents counterproductive activities, which in turn produces mutual benefits to all parties involved. Some types of contractual arrangements can facilitate achieving unity of purpose. For example, various types of Relationship Contracting, Partnering, or Alliancing (Quick, 2002; Rahman & Kumaraswamy, 2004) are particularly developed to align project parties.

Conclusions

This case study provides evidence consistent with some of the basic assumptions of CCPM. Some of these assumptions are: considering uncertainty as the core cause for projects' undesirable effects, overestimation of task time in the form of buffers, and wastage of such safety time. Nevertheless, the case indicated that the absence of centralised priorities for the project was a challenge in adopting CCPM. Particularly elimination of deterministic start dates would negatively impact contractor's throughput rate. This is because contractors are involved in multiple projects and their throughout would increase only by increasing working days of their crew. Therefore, they would not risk having their crew waiting. It is argued here, in the context of this project, that CCPM has identified the core problem. However, implementation of the CCPM solution requires unity of purpose across project actors, in order to be able to prioritize several contractors across several projects. If unity of purpose could be achieved, then this would facilitate CCPM application and bring mutual benefits to all parties involved.

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