

Henry Deacon & Elma van der Lingen

The use of the critical path and critical chain methods in the South African construction industry

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Abstract

The purpose of this article is to report on an investigation of the use of critical path and critical chain methods in the South African construction industry. Through a questionnaire survey, data was collected to establish which construction sectors apply these methods, the percentage of construction professionals using these methods, the reasons why these methods are applied, and the factors that influence the use of these methods.

Based on the findings, the critical path and critical chain methods are mostly used in the South African construction industry by the building sector, in comparison to the civil and industrial sectors. The critical path method is used more than the critical chain method, with over 70% of the responding companies applying the critical path method and only 22% applying the critical chain method. The latter method is considered to be a relatively new project management tool and requires a culture change in the company. Users of the critical path method believe that the method mainly improves their project understanding, planning, scheduling and control, with all these improvements ultimately leading to better on-time completion of projects and cost saving.

Keywords: Critical path method, critical chain method, construction, project management, CCPM

Abstrak

Die doel van die artikel is om die Suid-Afrikaanse konstruksiebedryf se gebruik van die kritiese padmetode en die kritiese kettingmetode te ondersoek. Data is deur middel van 'n vraelys ingewin om te bepaal watter konstruksiesektore die metodes gebruik, asook die persentasie-gebruik deur professionele persone in die konstruksiebedryf, die onderliggende redes vir die toepassing van die metodes en die faktore wat die gebruik hiervan beïnvloed.

Die navorsing het bevind dat die kritiese padmetode en die kritiese kettingmetode in die Suid-Afrikaanse konstruksiebedryf meer in die bousektor gebruik word

Mr Henry A. Deacon: M.Eng. student, Graduate School of Technology Management, Department of Engineering and Technology Management, University of Pretoria, Pretoria, South Africa. Phone: 012-4205939, Fax: 012-3625307, email: <henryadeacon@gmail.com>

Prof. Elma Van der Lingen, Graduate School of Technology Management, Department of Engineering and Technology Management, University of Pretoria, Pretoria, South Africa. Phone: 012-4205939, Fax: 012-3625307, email: <elma.vanderlingen@up.ac.za>

as in die siviele en industriële sektore. Die kritiese padmetode word deur meer maatskappye en op meer projekte gebruik as wat die kritiese kettingmetode deur die konstruksiebedryf gebruik word, met meer as 70% van die responderende maatskappye wat van die kritiese padmetode gebruik maak teenoor 22% wat die kritiese kettingmetode gebruik. Die laasgenoemde metode word as 'n jong metode beskou en implementering vereis kultuurveranderinge in die maatskappy. Gebruikers van die kritiese padmetode glo dat die metode help met die verbetering van projekbegrip, beplanning, skedulering en beheer, met al die verbeteringe wat lei tot beter optydafsluiting van projekte en kostebesparing.

Slutelwoorde: Kritiese padmetode, kritiese kettingmetode, konstruksie, projekbestuur

1. Introduction

The critical path method (CPM) has been in use for approximately 55 years (Dilmaghani, 2008: 10) and has become the construction industry's main standard for project scheduling. The critical chain method (CCM) has been in use for only 17 years (Goldratt, 1997).

Since its introduction in the late 1950s, the CPM has proven to be a useful tool for planning and controlling construction projects (Dilmaghani, 2008: 10). The CPM allows project managers to identify critical activities by evaluating the times when activities can start and finish, determining activity float, and assessing the effect of adjustments in duration and logical relations on the overall project duration. Over the past three decades, the use of the CPM has drastically increased in the construction industry, due to its benefits and the noteworthy advancements that have been made in both computer hardware and scheduling software. The CPM is a valuable asset for construction projects, because it enables contractors to determine resource requirements, vendors to finalise material deliveries, and subcontractors to establish when work can be performed.

Goldratt's book *Critical chain* (1997) introduced the CCM, often referred to as critical chain project management (CCPM), as a new technique for scheduling, monitoring and controlling. Any organisation that implements this relatively new methodology hopes to make the most of the opportunity to reduce the project completion time significantly. The theoretical basis of the CCM, the theory of constraints (TOC), claims that the weakest link in the system determines construction efficiency (Goldratt & Cox, 1984). Therefore, the core factor influencing the efficiency of construction is the capability of the weakest link. According to Goldratt (1997), the critical chain is the longest path formed from resource balances on the basis of a detailed consideration of the logical and resource constraints that exist between project activities.

No comprehensive, structured investigations have been conducted to establish what circumstances influence the utilisation of the CPM and CCM in South Africa's construction industry. Furthermore, no publications differentiate the factors associated with the implementation success of the CPM and CCM in this sector in South Africa. Therefore, South African construction professionals' experience and use of the CPM and CCM are unknown. The primary focus of this article is to determine the application of the CPM and CCM in the South African construction industry with the following subobjectives:

- To determine which of the construction sectors (building, civil and/or industrial) apply the CPM and CCM.
- To obtain the percentage of professionals who use these methods.
- To define the prevailing reasons why these methods are applied.
- To clarify the factors that influence the use of the CPM and CCM.

2. Background

2.1 Development of the critical path method

Henry Laurence Gantt introduced the Gantt chart (bar chart) in 1916 (Weaver, 2012: 7). Since then, bar charts have been used extensively for planning and monitoring construction projects. Menesi (2010: 10) states that, although this is a simple format that efficiently communicates the required information, such bar charts have restrictions, as the logical relationships between activities are not considered. This complicates the updating of the schedule as the project progresses. In the late 1950s, E.I. Du Pont de Nemours Company, as well as the Univac Applications Research Centre of Remington Rand collaborated to develop the CPM, which is based on the bar chart (Dilmaghani, 2008: 10).

The CPM is an algorithm for scheduling a large number of activities in complex project plans, where the "critical path" is the sequence of dependant tasks, where if there is a delay, will cause the end date to move out (Stelth & Le Roy, 2009: 23). For example, a project manager can determine the critical path of activities by evaluating the start and finish times of activities, determining the activity float/delay and assessing the effect of duration modifications.

2.2 Development of the critical chain method

In their book entitled *The goal: A process of ongoing improvement*, Goldratt & Cox (1984) introduced the TOC as an operations management method with the purpose of continuously improving

profit, return on investment, and cash flow. The TOC considers that the total system output is determined by a bottleneck or single constraint, with the best possible system performance being accomplished by managing the constraint. The TOC emphasises that constraints and non-constraints require different management and behavioural rules to manage flow by allowing for uncertainty, for example, rework and unscheduled stoppages. The TOC proposes a five-step sequence: identifying the constraint, exploiting the constraint, subordinating the constraint, elevating it, and repeating the process (Pretorius, 2014).

Goldratt extended the TOC to the project environment by introducing the concepts of the CCM in his book *Critical chain*, which offers a better understanding of how the TOC concepts can be applied to single- and multi-project environments. In TOC, the constraint determines system (organisational) performance. Similarly, in projects, TOC states that the critical path determines project performance. Thus the constraint in a project is the critical path (Goldratt, 1997).

The purpose of the critical chain is to enable projects to finish promptly, within budget, and without curtailing the project scope. Cook (1998: 21) summarised the following key features of the critical chain:

- It is a cultural change in project management.
- Multi-tasking is avoided.
- It accumulates all safety buffers at the end of the project instead of building them into activity estimates, and protects the critical chain against insecurity.
- It focuses on the project constraint (the longest chain of dependent resources or activities).

Different terminologies for the CCM are also used in the literature, for example, CCPM (Dilmaghani, 2008: 2), critical chain scheduling (CCS) (Yang, 2007: 25), and critical chain scheduling/buffer management (CCS/BM) (Herroelen, Leus & Demeulemeester, 2002: 48).

2.3 Comparison and differences between the CPM and CCM

The Project Management Institute (2013: 176-178) defines the critical path, the CPM, the critical chain, and the CCM as follows:

- The critical path is the longest link of successive activities that determines the project completion date on a schedule,

where the entire schedule will be delayed by delays in the critical path.

- The CPM is the method used for planning, monitoring and controlling the project schedule based on the determined critical path.
- The critical chain is the longest link of successive activities taking resource constraints into consideration, where the completion date of the project is only finalised after a project buffer has been added to the end of the critical chain.
- The CCM is the project schedule planning, monitoring and controlling method that uses the critical chain, first, for scheduling, by determining the critical chain and buffers and, secondly, for monitoring and controlling the project schedule in terms of the buffers.

The safety buffers (SB) of the CPM schedule are included in each activity (see Figure 1), whereas CCPM refers to a single project buffer (PB) at the end with the CCM. Feeding buffer (FB) is located wherever a non-critical path feeds into a critical path. The CPM is further only used on a single-project basis, while the CCM can be used as a multi-project scheduling solution, in addition to its applicability for single-project use (Lechler, Ronen & Stohr, 2005: 53).

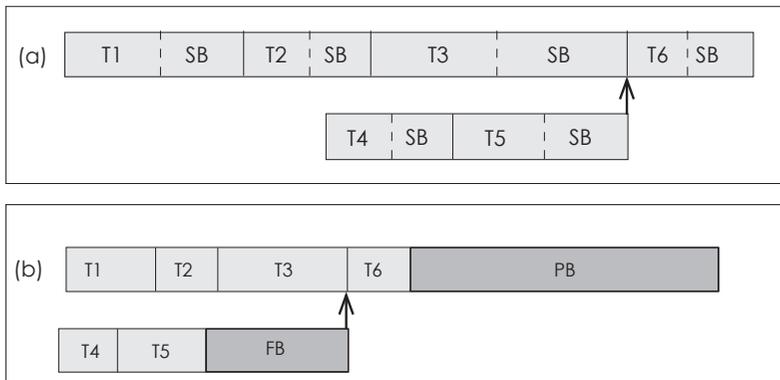


Figure 1: The (a) CPM with implicit safety buffers and the (b) CCM with explicit project buffers with T = task; SB = safety buffer; PB = project buffer; FB = feeding buffer.

Table 1 provides a comparison of the main characteristics of the CPM and CCM as adapted from Stelth & Le Roy (2009: 32-33).

Table 1: Comparison of the CPM and the CCM

Characteristic	Critical path method	Critical chain method
Project finishing date	A realistic date is believed to be met.	It has a high level of probability and is assured throughout with buffers.
Project schedule	CPM establishes the project start and end. The path can be adjusted during the project.	CCM determines the end of the project, but the start is often determined by a non-critical activity. The chain does not adjust.
Project variation	Variation is implicit and expected to balance out throughout the project.	Variation is explicitly planned and handled during the project with buffers.
Schedule management	Each activity must be kept on schedule according to the calendar in order to keep the project on schedule.	Buffers are managed to absorb variation efficiently in order to keep the project on schedule.
Schedule tracking	Activity starts and finishes are thoroughly tracked. Schedule slippage is important and must be monitored closely.	Buffer status is thoroughly tracked. When any task starts or finishes with respect to the calendar is insignificant.
Task completion	People are assessed in terms of whether or not their tasks are late with regard to their committed calendar date for activity completion.	Half of all tasks are anticipated to take longer than scheduled and the buffers absorb such variation.
Project reviews	Fixed reviews are scheduled to assess the project progress to date.	Floating reviews are set off by phase completion and buffer status is reviewed for the probability of project completion.
Non-critical activities slack	The total slack that non-critical paths have is irrelevant and not monitored.	Non-critical activities should have adequate feeding buffers to protect the critical chain.
Resource management	Resources should be multi-tasked to make progress on every project.	Multi-tasking of resources is avoided at all costs.

2.4 Use of the CPM and CCM by construction industries

Several surveys have confirmed that the use of the CPM in the construction industry has been growing over the years. Kelleher (2004: 36) analysed the data from three surveys conducted in 1974, 1990 and 2003, respectively. These surveys investigated how the top 400 contractors in the USA, as identified by *Engineering News Record (ENR)*, used the CPM. The study revealed that the CPM was used on

75% of contracts and was regarded as a valid management tool by 98% of the respondents in 2003.

Given the mixture of both small and large contractors, Hawkins (2007) conducted a survey in 2007 that proved that small and medium-sized construction firms also utilise the CPM for project management and that it is not only the ENR's large top 400 firms that do so.

A study by Georgy, Marzook & Ibrahim (2013) revealed that the main reasons why construction professionals in Egypt and Saudi Arabia use the CPM are that no highly sophisticated skills are required; it assists in dispute resolution; it is valued as a management tool; cost and time are saved, and it is mostly a contract requirement.

Georgy *et al.* (2013: 8) state that, of the construction professionals in Egypt and Saudi Arabia, 10% and 44% of the respondents, respectively, were of the opinion that the CCM does not add any genuine value to project planning. However, the CCM is appreciated as a fresh and innovative methodology.

2.5 Criticism of the critical path method

The study by Kelleher (2004: 38) indicated that the CPM's disadvantages are excessive implementation work, logic abuse, too much reliance on specialists, and lack of awareness of field personnel requirements. Contractors may find the CPM beneficial for progress status analysis and updating activity data, but not as useful in supporting other essential aspects, such as corrective actions and identifying execution problems. Kuhn (in Hegazy & Menesi, 2010: 1078), states that, while the owners and managers of contracting companies recognise the value of using CPM, contractors cannot use it effectively, because the critical path does not reflect reality. This is supported by Menesi (2010: 2) who states that the CPM algorithm is based on two idealistic assumptions during the project planning stage, namely that resources are limitless and that the project deadline is unrestricted.

2.6 Criticism of the critical chain method

Trietsch (2005: 33) claimed that most of Goldratt and Cox's concepts preceded the publication of their book *The goal: A process of ongoing improvement*. For example, he referred to a book by Pervozvansky as the original idea of the constraint. However, he conceded that Goldratt made a notable contribution to project management. Steyn (2001: 368-369) states that the application of

the TOC to project management was not customary prior to the introduction of the CCM, and he quotes sources that argued that the critical chain philosophy derived a great deal from old-fashioned methods. In a case study, Lechler *et al.* (in Repp, 2012: 45) pointed out that a reason for failures of the CCM was that the critical chain was becoming extremely difficult to manage, as there were too many buffers. Herroelen *et al.* (2002: 59) state that it is possible for different software packages to determine completely diverse critical chains and non-minimal baseline schedules, with the critical chain then having to be selected randomly.

The literature reveals that a higher percentage of construction professionals are now using the CPM than in the past. It is hard to identify any single reason why use of the CPM has grown; it is rather a combination of factors. Overall, users of the CPM are of the opinion that they are successfully reaping the benefits of the method. The literature further uncovers that the CCM, although it may be successfully implemented in certain industries, is still unfamiliar in the construction industry. Though many construction professionals have doubts about achieving positive results with the implementation of the CCM, many still expect partial success.

3. Research methodology

3.1 Research questions and hypotheses

This research study is descriptive and conclusive, as it is aligned with the identified research questions and hypotheses. Table 2 indicates the research questions and hypotheses that were formulated for this research study.

Table 2: Research questions and hypotheses

Number	Questions	Hypotheses
1	What types of construction companies (building, civil or industrial) use the CPM in South Africa?	H1: The CPM is used by all types of construction companies in South Africa.
2	What types of construction companies (building, civil or industrial) use the CCM in South Africa?	H2: The CCM is used by all types of construction companies in South Africa.
3	What is the percentage of construction professionals' use of CPM in South Africa?	H3: The CPM is implemented by approximately 90% of construction professionals in South Africa.

Number	Questions	Hypotheses
4	What percentage of construction professionals in South Africa use the CCM?	H4: The CCM is used by approximately 15% of construction professionals in South Africa.
5	Why do construction professionals in South Africa use the CPM and the CCM?	H5: Construction professionals in South Africa use the CPM and the CCM mainly for project scheduling, tracking, and control.
6	What factors influence the use of the CPM in the South African construction industry?	H6: The use of the CPM is mainly influenced by contract requirements.
7	What factors influence the use of the CCM in the South African construction industry?	H7: The use of the CCM is mainly influenced by improving systems throughput.

3.2 Research philosophy and approach

The philosophy that is associated with the research problem is the positivism paradigm, which is followed throughout the research process. The key concepts of the positivism philosophy are the following:

- i The researcher is detached from, independent of, and not influenced by the research subject.
- ii The research emphasises a highly structured methodology for replication intentions.
- iii The research produces quantifiable observation that can be examined statistically.

A deductive approach is more appropriate for a positivism paradigm, which classifies this research study as deductive or theory testing in nature. Zikmund (2002: 46-47) states that deductive reasoning involves the process of reasoning from one or several general statements in order to achieve a logical conclusion. The key concepts of the deductive approach are as follows:

- The approach forms a hypothesis or theory and devises the research to investigate the hypothesis.
- It is more oriented to positivism.
- It is scientific research.
- It strives to clarify fundamental relations between variables.
- It is more probable to gather quantitative data.
- The approach is very structured.

3.3 Methodology

The data collection tool was a questionnaire that was set up in an electronic web-based program (Survey Monkey). A questionnaire was deemed to be the most appropriate method of data collection for this research. Albaum, Wiley, Roster & Smith (2011: 687) state that it is fast becoming the favoured method of distribution for self-administered surveys. The questionnaire for this research is self-administered and respondents were contacted by email. The questionnaire design is based on closed-type questions. Zikmund (2002: 333) maintains that closed-type questions are easier to answer, as they require little skill and less time from respondents. The questionnaire consisted of three sections:

- The first section clarified the study and asked for basic information, such as the respondent's name, company name, and current management level. The purpose of these questions was to determine the company and the respondent's management position in the company.
- The second section tested the various respondents' application of the CPM. These questions were all pre-coded. An open-ended option was included in case the respondent's response did not fall into one of the pre-coded options provided. The purpose of these questions was to determine the application of the CPM in the South African construction industry.
- The third section tested the various respondents' application of the CCM. These responses were also pre-coded; with the choice of an open-ended response, should the response not fall into one of the pre-coded options provided. The purpose of these questions was to determine the application of the CCM in the South African construction industry.

Because descriptive research seeks to answer certain questions, Welman, Kruger & Mitchell (2005: 23) propose it to clarify the characteristics of a population or phenomenon. This research study is descriptive and conclusive, as it will be aligned with the identified research questions and hypotheses. Construction professionals' application of the CPM and the CCM is clearly defined and well researched by Kelleher (2004), Hawkins (2007), Repp (2012) and Honiball (2012), which substantiates the quantitative nature of this research.

A survey is believed to be appropriate for the collection of data and to accomplish the research objectives. The benefits of surveys are the reason for the selection of this strategy. Zikmund (2002: 195) highlights

that surveys can provide accurate, economic and fast means of attaining information for objectives. Saunders, Lewis & Thornhill (2009: 94) state that the survey approach affords the researcher more control over the research process.

Wyse (2012) highlights the following shortcomings of online questionnaires:

- Respondents may not always provide honest answers, as they could be concerned that they present themselves in a negative manner.
- Closed-type questions might give the survey a lower validity rate, as question non-responses could result in data errors. Bias could also be created if the number of respondents who choose to answer a certain question differs from those who choose not to answer.
- Self-administered surveys run the risk of having errors.

3.4 Population and sample

The contact information of members of the South African Council for Project and Construction Management Professionals (SACPCMP), Master Builders South Africa (MBSA), and the National Home Builders Regulation Council (NHBRC) was obtained from each organisation's website. These organisations represent employers and contractors who operate in the construction industry and are leading national representative bodies in this sector. E-mails requesting the company's participation in the study were sent directly to company staff members. The e-mails provided a link to the survey. Response to the survey was voluntary.

From the 321 companies, 63 respondents agreed to participate in the survey. However, 22 respondents were disqualified, due to incomplete responses. Therefore, 41 responses (13%) were used to evaluate the study's results. It is, however, not possible to conclude that the survey results represent the entire range of contractors. The low responses provided a limitation to the generalisation of the results to the entire industry. However, the results represent the section of companies/industries that chose to participate.

4. Results and discussion

4.1 Profile data on company and respondents

Figure 2 categorises the responding companies by size according to annual construction revenue. The majority (41%) of the respondents are from a large company with an annual construction revenue exceeding R50 million. The least number (27%) of respondents are categorised as medium-sized firms (annual revenue between R15 million and R50 million), and 32% represented the small company category with an annual construction revenue of less than R15 million.

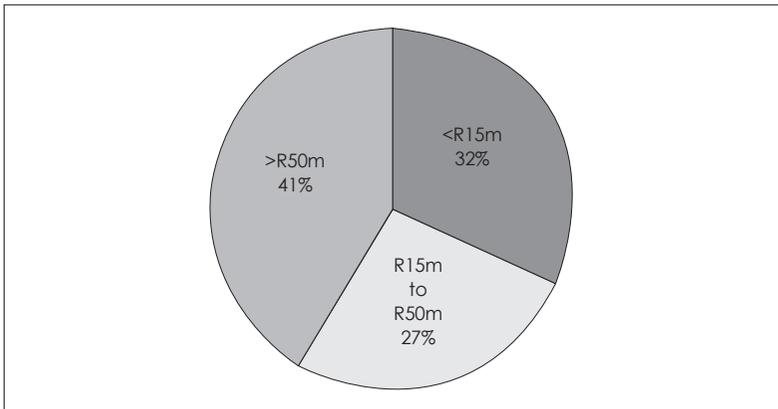


Figure 2: The size of representative companies according to annual turnover

Figure 3 indicates the construction industry sectors, in which the responding companies that use the CPM and the CCM are involved. The majority (59%) of the respondents conduct building construction, 41% civil construction, and 14% industrial construction. The "other" option was selected by 45% of the respondents and included electrical, mining and petrochemical construction, as well as regulation of the home-building industry, power plants, reticulation networks and solar energy. The survey results showed that 35% of the companies are involved in more than one construction sector.

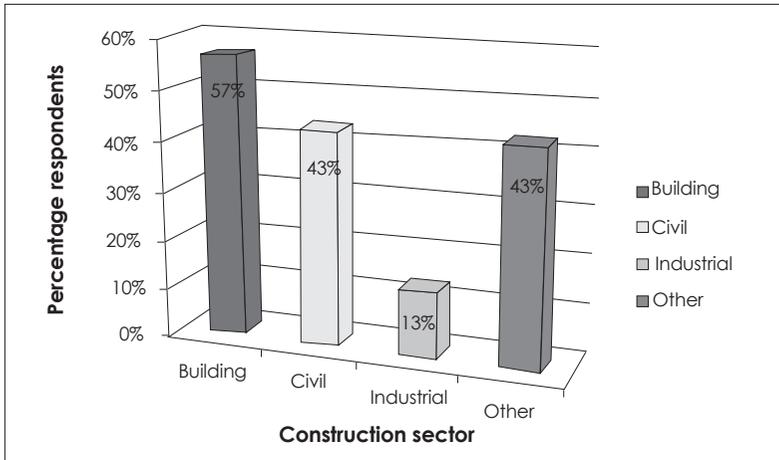


Figure 3: The different construction sectors in which the respondents who use the CPM and the CCM are involved

Table 2 illustrates that a relatively high percentage (34%) of the respondents are project managers who manage individual projects. The second-most selected option was “other” (27%) and included chief executive officers, provincial managers, proposal estimators, contract managers, co-managing directors, construction managers, and several quantity surveyors. These results indicate that the respondents represent a relatively wide distribution of positions within the companies.

Table 2: The respondents' positions within the companies

<i>Position in company</i>	<i>Main task</i>	<i>Response percentage</i>
Project team member	Works on project tasks	20%
Project manager	Manages individual projects	34%
Programme manager	Manages a portfolio of projects	12%
Senior management	Is reported to by project and programme managers	20%
Project management consultant	Provides guidance on managing projects	7%
Contractor	External contractor/subcontractor/supplier	2%
Other		27%

4.2 Use of the CPM and the CCM

The CPM was used more than the CCM, with over 70% of the responding companies applying the CPM and only 22% applying the CCM (see Figure 4). The majority (82%) of the large companies used the CPM, compared to 69% and 64% of the small and medium-sized companies, respectively. The majority of the smaller companies made use of the CCM, compared to medium-sized and large companies.

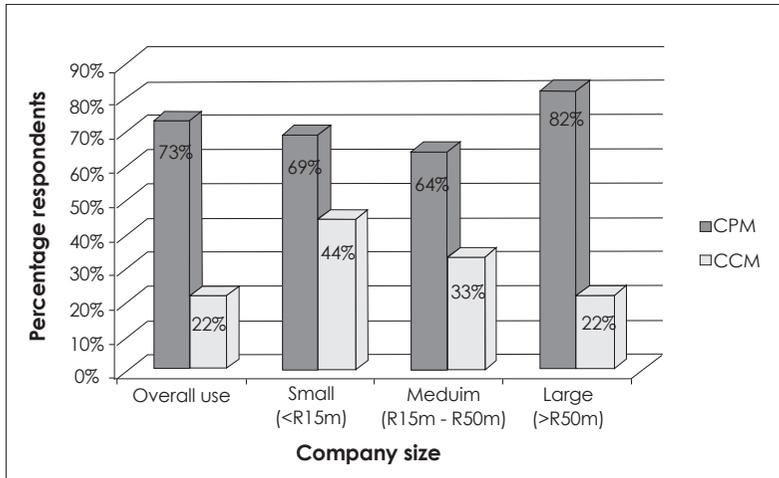


Figure 4: Overall usage of the CPM and the CCM according to company size (some companies make use of both CPM and CCM, resulting in >100%).

Figure 5 further indicates that for the companies making use of CPM and/or CCM, the smaller companies were mainly involved in building and civil construction, whereas the larger companies had a presence in all construction sectors. The industrial sector was dominated by the medium-sized industries.

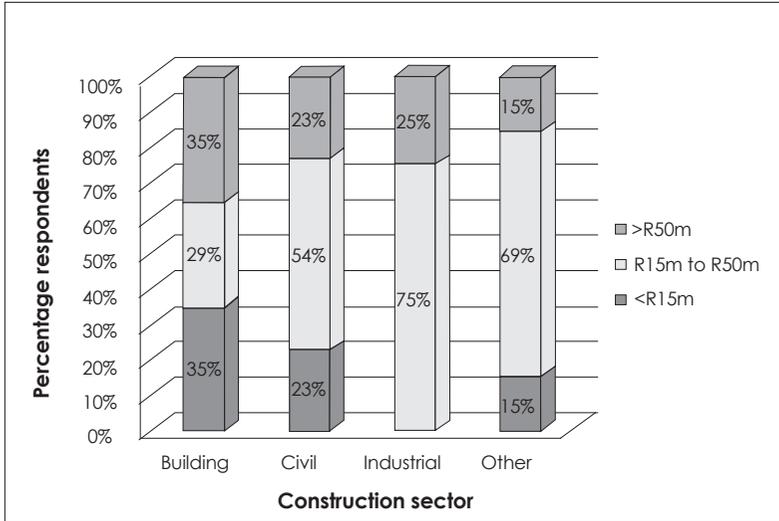


Figure 5: Graph indicating the construction sector and size of companies making use of CPM and/or CCM

Figure 6 summarises the regular use of the CPM and the CCM in relation to contracts. Approximately 34% of the respondents use the CPM for all contracts, whereas only 22% use the CCM for all contracts. Approximately 70% of the respondents use the CPM and the CCM on more than 50% of their contracts.

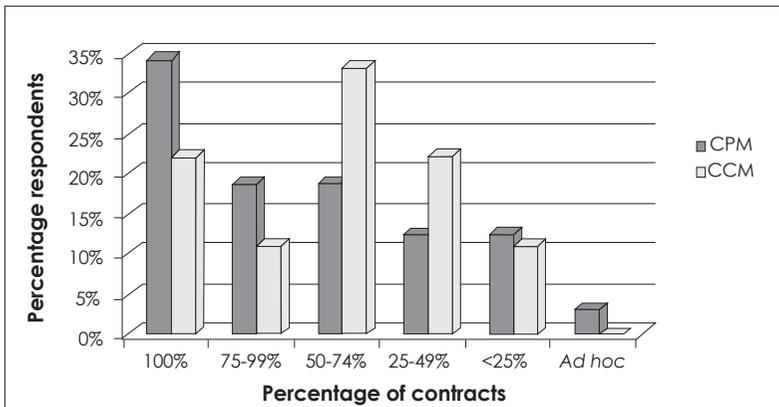


Figure 6: The regular use of the CPM and the CCM on contracts

The main reason why construction professionals use the CPM is because more than 80% of the respondents who apply the method consider it to be a valid management tool (see Figure 7). Other reasons are that it improves communication among project parties and is often a contract requirement, while it is also increasingly used in dispute resolution and litigation. In contrast to companies using the CPM, all the responding companies that use the CCM regard it as a valid management tool. Of the CPM and the CCM users, 72% indicate that it improves communication among the project parties, while only the CPM users apply it for dispute resolution, litigation and as a contract requirement.

Users of the CPM confirmed that the method mainly improves their project understanding, planning, scheduling and control, with all these improvements ultimately leading to more punctual completion of projects. The CPM is mostly used for planning and controlling construction work. More than 80% of the respondents who apply the method use it to plan their projects, while over 50% also use it to monitor and control project progress (Table 3).

Users of the CCM indicated that the method mainly improves their project planning, scheduling and response time to problems, which saves time.

On the other hand, the majority of the respondents who do not use the CPM indicated that they are unfamiliar with the method or see no need to use it, due to projects being relatively small. A few indicated that the method does not reflect reality. None of the respondents indicated that the method does not identify execution problems or does not support corrective actions.

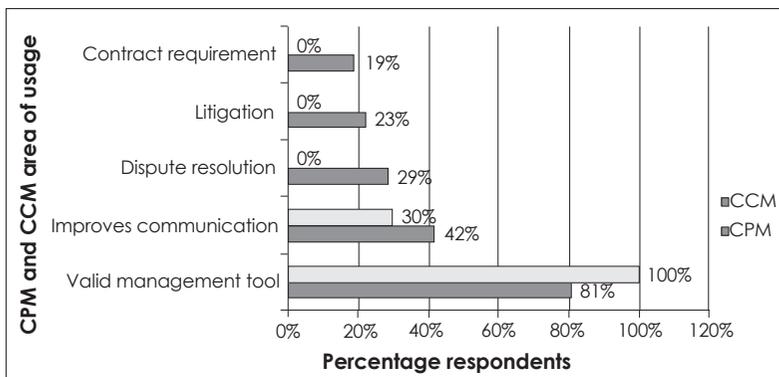


Figure 7: Reasons why companies use the CPM and the CCM

Table 3: Project areas where the CPM is applied

<i>Project areas</i>	<i>Response percentage</i>
Detailed planning of construction work	84%
Periodic control of construction work	55%
Operation and maintenance of projects	36%
Estimating and bidding	29%
Design development (conceptualisation, feasibility, etc.)	23%
Other	3%

Respondents who do not use the CPM provided reasons such as their projects being too small to justify the use of the CPM and the method being unnecessary for their needs, as well as it not reflecting the actual state of activities. The most prominent reason for not using the CPM is that companies do not regard the CPM as being problematic, therefore the CPM is deemed unnecessary.

They are further of the opinion that the CPM is too much effort to implement, with some companies simply being unwilling to embark on a culture change. The Besner and Hobbs (2008:16) survey-based study revealed that the use of the CPM was very limited, which the researchers partly accredited to the newness of the method.

4.3 Advantages and disadvantages of the CPM and the CCM

Although many companies see benefits in the application of the CPM, with the majority of the respondents stating that the method has no major disadvantages, some concern was also expressed. Figure 8 shows that the main perceived advantages of the CPM are improved planning, scheduling and project control. A further advantage is improved understanding of the project, which increases the on-time completion and reduces delays. Some of the users were concerned by the fact that the method depends too much on specialists, is not responsive to field personnel needs, and requires excessive implementation work.

In comparison, the companies applying the CCM also realise its benefits, with some users stating that the method has no major disadvantages for them. However, the concerns highlighted were that the CCM becomes difficult to manage when there are too many buffers and that the critical chain is not always clear after resource scheduling, since several chains could be identical. Improved scheduling and faster response to problems (both 78%) were

considered the main advantages of the CCM. Improved planning and time saving (both 67%) were the next most cited advantages.

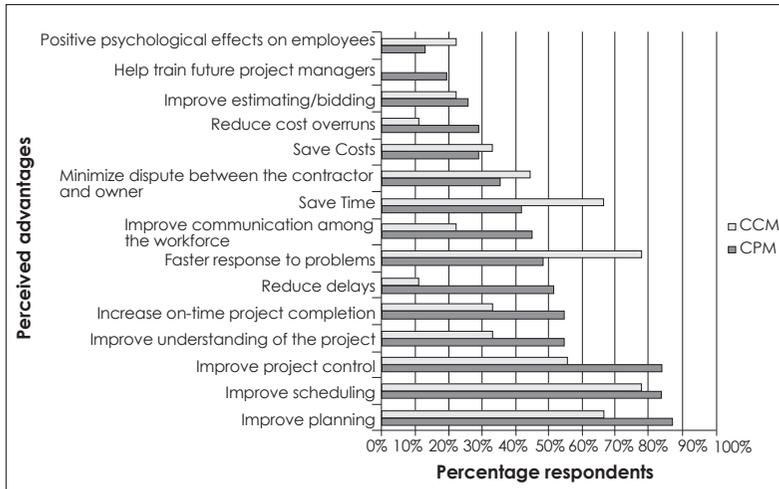


Figure 8: The perceived advantages of the CPM and the CCM

4.4 Importance of the CPM and the CCM for future company success

Generally, the CPM and the CCM are considered important methods to be used in the construction industry in South Africa. Only 3% of the respondents indicated that the CPM would likely be unimportant to their company's future success (see Figure 9). Furthermore, about 47% of the large companies and 36% of the medium-sized companies were of the opinion that the CPM should be deemed an important method for future projects. The CCM is mainly considered a moderately important method for future success, and only 22% of the respondents indicated that it will be very important in the future.

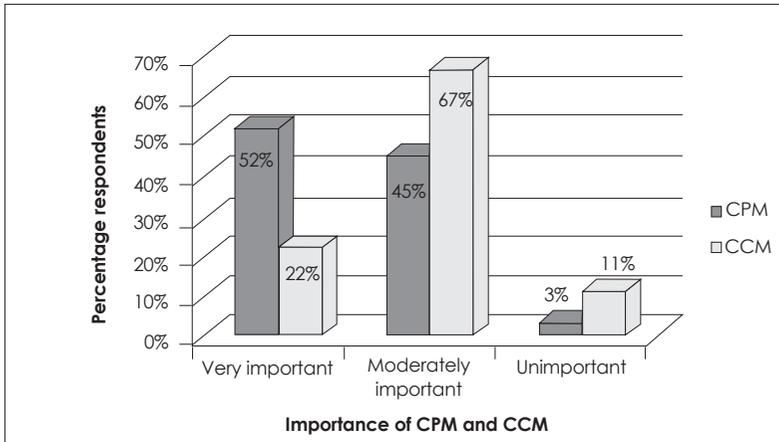


Figure 9: The importance of the CPM and the CCM to the future success of companies

CPM users are also of the opinion that they are more successful at achieving the advantages of the method than are users of the CCM. Large companies appear to get the most out of the CPM application. The fact that they use the CPM more frequently and trust the information provided by the method is probably the reason why nearly all of the companies regard the CPM as being moderately important to very important to their future success.

5. Conclusions

The primary focus of this paper was to determine the application of the CPM and the CCM in the South African construction industry, with the following subobjectives:

- To determine which of the construction sectors (building, civil and/or industrial) apply the CPM and the CCM
- To obtain the percentage of professionals who use these methods
- To define the prevailing reasons why these methods are applied
- To clarify the factors that influence the use of the CPM and the CCM

This study has established that the CPM and the CCM are proving to be versatile project scheduling tools in the South African construction industry. The results indicate that the CPM and CCM are widely used

in the building industry, closely followed by the civil construction industry. The CPM is used on more than 50% of projects by just over 70% of the respondents who apply the method, with 34% of users applying it on all their contracts. In comparison, the CCM is used on more than 50% of the projects by over 60% of the respondents who apply the method, with 22.2% of users applying it on all their contracts.

Large companies appear to get the most out of the CPM application. The fact that they use the CPM more frequently and trust the information provided by the method is probably the reason why nearly all the companies regard the CPM as being moderately to very important to their present and future success.

The respondents in this study found the CPM to be beneficial and consider it important to the general success of their companies. The main reason why construction professionals use the CPM is that more than 80% of the respondents who apply the method consider it a valid management tool. Other reasons are that it improves communication among project parties and it is often a contract requirement, while it is also increasingly used in dispute resolution and litigation. The CPM has grown over the years and it appears that it will continue to grow, based on the companies' views of the CPM's importance to their future success in South Africa.

The CCM is used less than the CPM. Although it is not a difficult methodology to grasp, it is still considered to be a relatively new project management tool. The CCM appears to be challenging to implement, as a shift in mindset, behaviour and culture is required in the organisation. CCM users believe that the method mainly improves their project planning, scheduling and response time to problems, which saves time.

The most prominent reason for not applying the CCM is that companies do not regard the CPM as problematic. Therefore, they deem the CCM to be unnecessary. They further believe that the CCM is too much effort to implement, with some companies simply being unwilling to embark on a culture change.

The responding companies that apply the method mostly regard the CCM as being moderately important to present and future success.

6. Recommendations

This study has identified the need for further research relating to the CPM and the CCM in South Africa. A brief description of the potential areas for further research is provided by formulating a hypothesis, or providing a brief problem statement:

- Construction companies in South Africa use the CPM and the CCM for single- and multi-project management.
- The success factors of the CPM and the CCM differ during each phase of the project life cycle.
- The expansion of this study to gain a bigger sample will contribute significantly to more verified results.

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