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PMBOK® and Critical Chain practices: antagonisms and opportunities for complementation

Práticas PMBOK® e Corrente Crítica: antagonismos e oportunidades de complementação

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Abstract: The endeavor of the Project Management Institute (PMI) in gathering and codifying valuable knowledge in the field of Project Management (PM) has resulted in A Guide to the Project Management Body of Knowledge (PMBOK® Guide). Goldratt has contributed to the body of knowledge in PM to develop the Critical Chain Project Management (CCPM) method, based on the Theory of Constraints (TOC). CCPM superficially recommended by the PMBOK® Guide introduces new concepts and methods aimed at PM, some of which conflict with the practices recommended by the guide itself. This research assumes that CCPM can bring significant benefits to the field of knowledge in PM and questions the little relevance given to it in the PMBOK® Guide. Therefore, the general proposal of the study is initially checking the degree of insertion of CCPM in the Guide, and then evaluating possible contradictions as well as opportunities for complementation between them. The analysis was based on a literature review and a field study with certified experts. Despite the fact that CCPM is recommended by the Guide as a method aimed at Time Management, the research indicated that other practices involving CCPM and not covered by the Guide can contribute not only to Time Management, but also to Human Resources and Communications. The research also found that CCPM is not self-sufficient in its practices, and the Guide should be referred to especially on Integration and Scope Management. It was further noted that CCPM conflicts with certain time-management practices recommended by the Guide that, if used concurrently, may potentially jeopardize the effectiveness of PM.

Keywords: Projects management; Critical Chain; PMBOK® Guide.

Resumo: *O esforço do Project Management Institute (PMI) em reunir e codificar o conhecimento de valor na área de Gerenciamento de Projetos (GP) resultou no A Guide to the Project Management Body of Knowledge (Guia PMBOK®). Goldratt contribuiu para o conjunto de conhecimentos em GP ao desenvolver o método Corrente Crítica (Critical Chain Project Management – CCPM), fundamentada na Teoria das Restrições (Theory of Constraints – TOC). A CCPM, superficialmente recomendada pelo Guia PMBOK®, apresenta novos conceitos e métodos voltados ao GP, parte dos quais conflita com algumas das práticas recomendadas pelo próprio Guia. Esta pesquisa assume que a CCPM pode trazer relevantes benefícios ao campo de conhecimento em GP e questiona a pouca relevância dada pelo Guia PMBOK®. Assim, a pesquisa tem como proposta global verificar inicialmente o grau de inserção da CCPM no Guia e, posteriormente, avaliar possíveis antagonismos entre eles, assim como oportunidades de complementação. A análise se baseou em uma revisão da literatura e em uma pesquisa de campo com especialistas certificados. Apesar de a CCPM ser recomendada pelo Guia como um método voltado para o Gerenciamento do Tempo, a pesquisa indicou que outras práticas que envolvem a CCPM, e não contempladas pelo Guia, podem contribuir não apenas para o Gerenciamento do Tempo, mas também de Recursos Humanos e Comunicações. A pesquisa apontou também que a CCPM não é autossuficiente em suas práticas, devendo recorrer ao Guia especialmente no Gerenciamento da Integração e Escopo. Foi indicado ainda que a CCPM se opõe a certas práticas de gestão do tempo recomendadas pelo Guia. Se aplicadas concomitantemente, elas podem potencialmente pôr em risco a efetividade do GP.*

Palavras-chave: *Gestão de projetos; Corrente Crítica; Guia PMBOK®.*

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1 Introduction

The *Project Management Institute* (PMI) is an international organization that promotes the creation of standards and knowledge in Project Management (PM), in addition to certifying professionals, called *Project Management Professionals* (PMP®), working in the area. The long-term commitment PMI has with management professionalization in projects, established the need to formally bring together and codify knowledge of value in the area. This effort resulted in the *Project Management Body of Knowledge* (PMBOK® Guide) of 1987, later being rewritten and renamed as *A Guide to the Project Management Body of Knowledge* (PMBOK® Guide) of 1996. The PMBOK® Guide is currently in its fifth edition (PMI, 2013).

Being a reference book, the PMBOK® Guide acts only as a general guideline for PM, and does not attempt to detail the methods and tools presented. PM knowledge in the guide, however, is not exhaustive. Eliyahu Goldratt contributed to the knowledge set in PM to develop the approach to Project Management based on *Critical Chain Project Management* (CCPM), founded on the *Theory of Constraints* (TOC). As with the PMBOK® Guide, CCPM also recommends a number of PM practices, but is explicit in condemning others. Its currently available body of knowledge has brought some important contributions to PM practices, such as (Cox & Schleier, 2010):

- Elimination of individual activity safeties and their aggregation in the form of time "buffers" to protect project completion deadlines;
- Specific techniques for resource leveling with respect to the preparation of individual project activity planning;
- Mitigation techniques for bad multitasking, as a result of a reduction of conflicts in resources use, especially in multi-project environments;
- Scheduling of projects according to the capacity limitations of the critical resource.

The work of Carvalho et al. (2013), for example, suggests the processes linked to the allocation of resources and to monitoring and control as a tendency within portfolio management research, demonstrating that CCPM tools meet current needs in the field of PM.

The *Theory of Constraints International Certification Organization* (TOCICO), in a way, is for TOC and for CCPM what PMI is for PM, that is, it is the body responsible for providing industry and individuals with internationally recognized standards, certifying practitioners, implementers and academics who have achieved a certain level of *expertise* in TOC (and not only in CCPM, therefore).

Despite there being an express increase in the number of scientific studies related to CCPM, this number is small when compared with the total number of studies in PM. Furthermore, with regard to the studies relating CCPM to practices recommended by the PMBOK® Guide, the scarcity of such research is even more significant, principally in national terms. Despite being a method studied for approximately two decades, the literature still identifies room for research that discuss the role of CCPM in the body of Project Management research, principally with regard to its interaction with other consolidated methods (Ghaffari & Emsley, 2015).

Despite an increase in academic interest for CCPM and for the performance it has achieved managing a wide variety of projects - in Millhiser & Szmerekovsky (2012) a list of large organizations which relate improvements with CCPM can be found -, the PMBOK® Guide only hesitantly recommends CCPM as a good PM practice. Furthermore, even though CCPM is mentioned by the PMBOK® Guide, there are managerial aspects that they exclude, such as recommending the Critical Path Method (CPM) Guide as a main reference for deadline management.

In this context, the current study starts from the assumption that the PMBOK® Guide omits certain CCPM practices, which could have been recommended. Furthermore, it does not explain the potential conflicts between these practices and others recommended by the Guide, compromising the effective establishment of guidelines for Project Management, and potentially leading to significant distortions in its application. Thus, this study looks to find answers to the following questions:

- What are the antagonistic elements – or conflicting premises - between the set of practices recommended by the PMBOK® Guide and by CCPM?
- What are the opportunities for complementation between the practices recommended by the PMBOK® Guide and by CCPM?

Accordingly, this study aims to identify potential opportunities for complementation between CCPM and the Guide, as well as pointing out the antagonisms of purpose between them.

2 Research method

The starting point for the study was a revision of the literature surrounding the principal research themes: Project Management, the PMBOK® Guide and CCPM. Based on the literature, antagonisms and opportunities for complementation in the Guide and CCPM were identified. A questionnaire was then prepared, to conduct interviews with specialists certified by PMI

or by TOCICO, aiming to validate or not the points raised. Structured questionnaires were used for the research - comprised of closed questions - but not disguised, meaning each respondent knew what the objective of the research was.

Specialists in PMBOK® and/or CCPM were interviewed, having been contacted by telephone and e-mail to explain the objective and importance of the project, and to verify participation availability. Two specialists in PMBOK®, two in CCPM and two specialists with knowledge of both the Guide and CCPM were selected for interview. The results of some questions were stratified (groups of specialists in PMBOK® and in CCPM). It was left to the experts to point out and comment on existing gaps in the practices recommended by the Guide or in CCPM. The specialists in both approaches (PMBOK® and CCPM), on the other hand, were urged to point out gaps in each approach, as well as identify antagonistic aspects between them. Following the interviews with specialists, the data was compiled and compared with the literature.

The questionnaire included 18 questions about the education and professional experience of each interviewee, principally in relation to projects. The other questions (19 to the end) were organized in five sections: General overview of PM (dealing with critical factors and obstacles observed in the practice of PM), General overview of PMBOK® (focusing on the areas and processes of the Guide that are most relevant or with a need for complementation), General overview of CCPM (seeking techniques and concepts of substantial impact or with greater limitations), PMBOK® and CCPM Visions (seeking opportunities for complementation among practices recommended by the Guide and by CCPM, in addition to evaluating how CCPM is approached by the Guide, including possible conflicts among the practices present in CCPM and those recommended by the PMBOK® Guide) and General Comments (open questions dealing with other PM content not forming part of the study but which could be seen as important for the interviewees).

The vast majority of questions solicited that the interviewee classify in order of importance the areas and processes of the Guide and the concepts of CCPM, as well as indicate which of these would require additional knowledge. This enabled a subsequent quantitative analysis of the data.

3 The PMBOK® Guide

The PMI – *Project Management Institute*, founded in 1969, is the leader and most widely known organization in terms of promoting PM practices. The PMI works to maintain and approve regulations and ethics in the field, and offers publications, training, seminars, Chapters (local associations interested in PM), special interest groups and faculties to promote the discipline of PM. It is recognized as a developer of standards *American National Standards Institute* (ANSI) and also has the distinction of being the first organization to have its certification program recognized by the *International Organization for Standardization* (ISO) 9001. The PMI boasts a worldwide association of more than 265,000 members from 170 different countries. Local PMI affiliations, called Chapters, meet regularly and allow project managers to exchange information and learn about new project management tools and techniques, or new ways to use established techniques. It offers six certificates that recognize knowledge and competence in PM, including the *Project Management Professional* (PMP®), credential obtained through the proficiency examination (Heldman, 2013).

In 1981, the PMI took formal measures to accumulate and codify relevant PM knowledge. This effort resulted, as previously mentioned, in the *Project Management Body of Knowledge* (PMBOK® Guide) of 1987, later being rewritten and renamed as *A Guide to the Project Management Body of Knowledge* (PMBOK® Guide) of 1996. The realization of the necessity to do so, became a long-term PMI commitment to the professionalization of project management. A new edition of the guide is launched every four years (Dinsmore & Cabanis-Brewin, 2014). The PMBOK® Guide is currently in its fifth edition. During the planning and execution of this study, the fifth edition of the Guide was still unavailable. Therefore, the study is based on the fourth edition. The changes brought by the new version of PMBOK® do not influence the results of this article, however, because the main changes refer to nomenclature and the organization of content in the Guide.

According to Dinsmore & Cabanis-Brewin (2014), the first edition of the PMBOK® Guide aimed to identify and describe generally accepted knowledge and practices, in other words, those that are applicable to most projects most of the time and on which there is general agreement regarding their value and utility. One major conceptual change for the current editions is that the PMI has substituted the criteria "generally accepted" in previous editions for "generally recognized as good practice". "Good practice" means there is general agreement that the correct application of these skills, tools and techniques can increase the chances of success in a wide range of projects. Good practice does not mean that the knowledge described should always be uniformly applied to all projects. The project management team is responsible for determining what is appropriate for a given project.

The Project Management Institute (PMI, 2008) presents the PMBOK® Guide as a recognized standard for the PM profession, being a formal document that describes established regulations, processes,

methods and practices. As with other professions such as Law and Medicine, the knowledge contained in the standard evolves from the good practices recognized by practitioners who have contributed to the development of it. The Guide provides guidelines for managing individual projects. It defines PM and its related concepts and describes the life cycle of PM and its related processes. The Guide also provides a common PM vocabulary, for discussing, writing and the application of PM concepts.

The fourth edition of the PMBOK® Guide organizes PM knowledge through the integration and application of 42 logically grouped PM processes, comprising five process groups. The fifth edition of the Guide considers 47 processes. The five PM process groups organize and describe how project activities should be carried, out in order to serve project requirements. The processes are classified as: Initiation, Planning, Execution, Monitoring and Control, and Completion.

These PM processes are also grouped according to the elements managed in a project (time, cost, scope etc.) that form the components of the PMBOK® Guide. From the 1996 edition of the Guide, integration management was added to the eight components already given in previous editions, these components being renamed as areas of knowledge in PM, with a separate chapter for each one (Dinsmore & Cabanis-Brewin, 2014).

A new area of knowledge was added in the fourth edition of the Guide, relating to interested parties (*stakeholders*). The content of this new area had already been included in the previous editions, merely being relocated to a new chapter. The nine areas included in the fourth edition of the PMBOK® Guide are presented in the following topics, along with a brief description of the processes contained in each area (PMI, 2008):

1. Integration Management: covers essential activities and processes to identify, define, unify and articulate all other topics related to the project;
2. Scope Management: what would summarize this area, is that the project should be delimited in a way that contains everything that is indispensable for the success of the project, and nothing more;
3. Time Management: all measures that guarantee the project will be completed within the deadline stipulated. It is in this area that the Guide mentions Critical Chain as one of the tools and techniques for developing an activities program for a project. More specifically, Critical Chain is presented as one of eight tools or techniques for time management. Critical Chain is defined in two paragraphs, just as the project and feeding buffers, and the basic way of managing them, are briefly conceptualized. These concepts are presented in greater detail in the next section;
4. Cost Management: is composed of project financial monitoring activities, that is, evaluating costs, determining the budget and the exercise of its control;
5. Quality Management: a set of activities and processes that, by means of quality policies and tools, ensures that the project meets specifications determined during project planning;
6. Human Resources Management: brings together the development and management processes of the project team. Seeks, through administrative and behavioral tasks, to utilize and enhance the potential of the people involved in the project - among others, customers, suppliers and employees;
7. Communications Management: covers all activities that, in some way, deal with information during the phases of the project, guaranteeing decision-making support to those involved. These activities include the production, collection, storage and destination of information;
8. Risk Management: the process by which project risks are identified, systematized and monitored. It involves planning the occurrence of possible unexpected events and the solutions applied to related issues, should they occur;
9. Acquisitions Management: Relates to the process of acquiring the external resources necessary for a project, such as products and services from other organizations.

4 Project management by critical chain

Since 1997, TOC has sought to develop applications in the scope of PM. One such application is the programming of a single project, in order to reduce the duration of the project and to simplify its control. This is the main theme of the book, Critical Chain (Goldratt, 1997), also written by Goldratt, which gives its name to the TOC approach for PM (CCPM – *Critical Chain Project Management*). Only in the final part of the book is there any indication of a future application for allocating shared resources in multiple projects. However, the application of CCPM in multi-project environments is currently available, and a synthesis of its concepts is presented in this article in due course.

4.1 General CCPM concepts and their application in single-project environments

CCPM has a clear focus on project time management. This does not mean, however, that the budget and scope aspects are neglected. A first basic premise of CCPM is that appropriate time management offers significant benefits for both scope and cost management (for example, a delayed project incurs a cost increase and/or cut in the initial specifications to ensure timely delivery). A second basic premise is that the traditional way to add safeties to the individual activities of a project is at the root of the problems observed in time management practices (Goldratt, 1997).

In PM environments, there is typically a significant degree of uncertainty with respect to the conditions in which the project will be executed. Uncertainty describes the degree to which it is difficult to predict any particular result before it occurs. In order to guarantee the results of a given project, despite the existence of uncertainty, a reserve is included to accommodate much of the variability. This reserve is generally in the form of an increase in the planned duration or budget.

Adding unnecessary safety, however, can significantly increase the expected duration and budget of a project, generating a sense of pressure to minimize this additional project safety. As a result of this pressure, in order to ensure that there is sufficient protection in each project plan to make agreed commitments attainable, PM practices have focused on "disguising" the existence of excessive protection, embedding safety into each task or activity to ensure that the probability of completing the project on time and within budget is reasonably high (Newbold, 1998; Robinson & Richards, 2010).

For CCPM, the projects fail, even with this excess of protection, due to the specific behavior of project team members. These archetypal behaviors are (Robinson & Richards, 2010):

- Procrastination or Student Syndrome: to have more than sufficient time to carry out a task is enough reason to let time pass before investing any serious effort in its completion. Added to this is the fact that there are frequently other more urgent responsibilities to receive attention, and the other tasks will only be carried out when their level of urgency is sufficiently high to justify the effort to complete them;
- Parkinson's Law and the failure to report advances: tasks are programmed with enough safety to cover almost all problems that may occur. However, it is rare for all possible problems to appear in one specific task. Thus, for the majority of activities, the organization will have, on completion, an excess of time and resources. Frequently, however, the unused safety is seen negatively as a sign of willful overestimation on the part of who defines the duration of the activity. For this reason, there is a reluctance to report the existence of unused safety. The result of this behavior, where tasks tend to occupy all the time and budget allocated to them, is referred to as Parkinson's Law;
- Bad multitasking: in some organizations focused on projects, resources are not dedicated just to one isolated project. This happens because, frequently, it is difficult to plan a project in a way that efficiently balances the load on all resources, ensuring that they will be used efficiently. There is a cost related to resource inactivity time, that is, when this resource is available to be used when necessary. One possible measure to reduce this cost is what is referred to as multitasking. In its simplest form, bad multitasking occurs when there is such a demand for the resource, that it is forced to interrupt each task before its conclusion in order to work on another task. However, the negative effects are difficult to detect because, due to multitasking, the resource seems to have constant demand, thereby being fully utilized. Pressure is frequently exercised in such a way that the resource is forced to show progress in all the tasks that are waiting, even though this means delaying the conclusion of a previously started task. Because of task breaks occurring before tasks have been concluded, and the adjustment times necessary to resume an unfinished task, all tasks are completed late in relation to the initial plan.

The starting point for the application of CCPM in a project is a list of tasks, together with their estimates of duration and dependencies. The first step involves developing an initial schedule for the project tasks. This is done taking into account the dependencies between tasks (as reflected in the project network) and the availability of resources. Once at least some of the resources have limited availability, the resulting schedule is susceptible to being longer than the scheme obtained with the basic algorithm of the *Critical Path Method* (CPM), because critical activities are delayed as they wait for the resources they need (Rand, 2000).

CCPM identifies "Critical Chain" as a set of tasks that results in a longer path for the conclusion of a

project after the leveling of resources. The critical chain supplies the conclusion date forecast by the project. These resources, demanded by the tasks in the critical chain, are defined as "Critical Resources". The next stage in CCPM planning involves recalculating the project schedule, based on smaller estimates for the duration of activities. CCPM affirms that the original duration estimates are those where the probability of completion is 95%, and that they should be reduced to the point where the probability of completion is 50% (Raz et al., 2003).

Figure 1 summarizes the transition of CPM to CCPM in the planning schedule. The duration of each activity on the schedule is represented by the length of its block. First, the safety of individual tasks is removed, and conflicts between resources then eliminated. The activities represented by a given letter are executed by the same resource, being unable to be done in parallel (resource leveling). Finally, the Critical Chain is defined as the longest path of activities after the withdrawal of individual safeties and the elimination of conflicts between activities sharing the same resource. In Figure 1, the critical chain is shown in gray.

The way CCPM deals with uncertainty is related to what are called *Buffers*. Buffers appear as activities on the project plan, but there is no work assigned to them. According to Leach (1999), CCPM protects the project conclusion date by means of the *Project Buffer*, collocated at the end of the Critical Chain. This buffer exploits the statistical law of aggregation, protecting the project from the uncertainties of individual activities by using buffers at the end of the path.

Yang & Gao (2011) present several methods of buffer dimensioning. One of the more mathematically simple is known as the *Cut and Paste Method*, proposed by Goldratt himself. The buffer size would be 50% of the total security times allocated in each task. Newbold (1998) proposes a more elaborate method, taking twice the standard deviation of the time securities assigned to each task as the buffer size.

Other buffers proposed by CCPM are (Budd & Cerveny, 2010; Herroelen & Leus, 2001; Leach, 1999):

- *Feeding Buffer*: CCPM protects the Critical Chain from delays in paths that feed it by allocating a buffer at the end of each of these paths. This includes paths that bring together the Critical Chain at the end of the project. This buffer provides a way of following noncritical pathways, keeping the focus on the Critical Chain;
- *Resource Buffer*: protects the Critical Chain from the non-availability of resources. It is a warning for project and resource managers to ensure that Critical Chain activity resources are ready as soon as the activity is ready to start. Resource Buffers do not use Critical Chain time, being only signals. CCPM only applies these buffers to Critical Chain activities, because the feeding buffer already provides additional protection to the other activities.

Figure 2 shows the insertion of project and feeding buffers to the schedule presented in Figure 1. The buffer sizes were calculated using the *Cut and Paste,* method, that is, half of the protection removed.

Traditionally, the progress of a project is measured according to the percentage of work completed in relation to the total estimated work. TOC refutes this type of measurement, since it does not focus attention and resources at the right point (Newbold, 1998). In its place, CCPM makes use of *Buffer Management* (BM).

Budd & Cerveny (2010) claim that another important use of CCPM buffers is providing a tool to help project managers know when to take action and when interference is unnecessary. In this sense, Buffer Management provides an environment with priorities that are updated and constantly applied throughout the organization on an hourly, daily or weekly basis. In order to assist decision making, a set of support practices has also been developed to adapt the prioritization system.

To calculate buffer consumption, project management should have up-to-date information about each task that has been started and not yet completed. At each verification point (daily or one or two times per week), the amount of time remaining to complete a task should be requested from each project team member currently working on a task. It is unproductive, for project management purposes, to request a conclusion date, or percentage of the work that has been concluded. The estimate of time "remaining" is needed for project management to know if some measure should be taken. The time remaining, added to the time elapsed since the task was started, can be compared with the initial time estimate to determine buffer penetration or recuperation. The time remaining changes (that is, not always decreasing) each time a consultation is made. If the sum of the time remaining and time elapsed are greater than the estimated duration (with reduced estimates), the buffer penetration increases by an amount equal to the difference between the sum and the estimated duration (Budd & Cerveny, 2010).

The amount of buffer utilized provides project management with information about the state of the project and when to take corrective action. The buffers

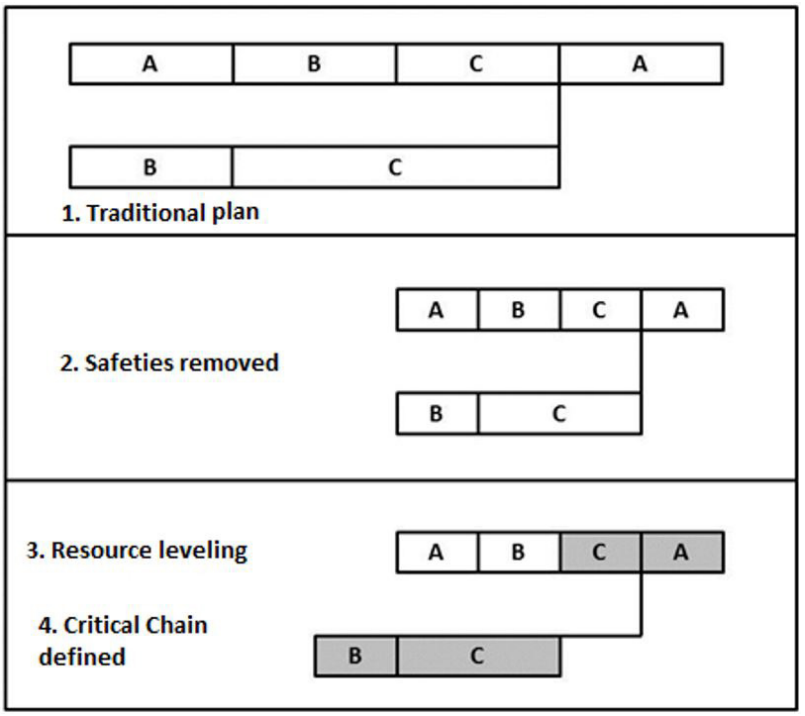

Figure 1. Transition of the traditional program to a program based on CCPM. Adapted from Robinson & Richards (2010).

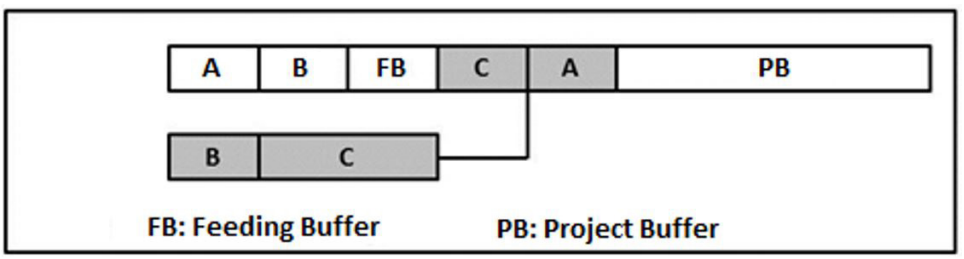

Figure 2. Insertion of buffers in the schedule. Adapted from Robinson & Richards (2010).

can be divided into three equal time parts that indicate, respectively, "expected variation", "normal variation" and "abnormal variation". Penetrating one-third of the buffer (the so-called green zone), those involved with the project need not take corrective action. The utilization of the second third of the buffer (yellow zone) is generally due to uncertainty inherent in the task duration forecast. Small operational variations in a project are no reason for alarm, but if the second third of the buffer starts to be used to cover delays in tasks, plans should be formulated to recuperate the lost time. Abnormal variations are generally the result of unique events beyond the normal course of project operation. Such events can be simple, such as an insufficiency or lack of a resource, or impacting, such as a natural disaster. When the red part of the buffer is penetrated, it is definitely time for action, and the execution of those plans made while buffer consumption was in the yellow zone (Agarwal et al., 2009).

TOC proposes further concepts focused on CCPM operationalization, such as *full kitting* and project freezing (discussed in the next topic). According to Budd & Cerveny (2010), ideally, no project should be started unless all the specifications have been presented, an acceptable schedule has been approved, and all the preparatory stages have been completed. In addition, no task should be started unless all required materials are available and the task is at the beginning of a working queue with FIFO (*First in First out*) logic. Having everything ready in hand before starting a project or task is referred to as a having a *"full kit"*. *Full kitting* is the process of elucidating project requirements, project approval by the parties involved, preparation of materials and resources for use, and all other actions necessary to ensure good project execution. It is important to

distinguish between *full kitting* and actually doing the tasks: activities that allow project tasks to be done without interruption are included in the *full kit* list, while activities that directly form part of a project's progress are excluded (Budd & Cerveny, 2010; Realization Technologies Inc., 2010).

According to Manhães (2011), the transition of traditional PM methods to CCPM is an implementation of substantial proportions, presenting several difficulties related to communication and synchronization. One TOC tool is particularly important for dealing with these challenges: *Strategy and Tactic Trees* (S&T).

The purpose of S&T is to offer the conditions necessary to achieve what is called Viable Vision, which, in summary, is a set of strategies to resolve market constraints, creating competitive advantages, and occurs when a company grows continuously and with stability. In addition to presenting the conditions for Viable Vision achievement, S&T indicates the specific changes necessary (excluding that which is unnecessary) at each level and for each function of an organization. This network of cause and effect relationships orientates the implementation process of CCPM and aids communication, whether horizontal or vertical, between those involved in the process (Barnard, 2010).

Change Management has, therefore, received special attention from TOC as a means of increasing the chances of success in its implementations, such as in the use of CCPM, for example. In addition to S&T Trees, some concepts and tools have been developed with the purpose of supporting change processes, notably the ten Layers of Resistance to change (Dettmer, 2007; Goldratt-Ashlag, 2010) and Criterion for Success (Barnard, 2010).

4.2 Multi-project management according to CCPM

CCPM assumes that resources are essentially fixed and that multiple projects should be staggered based on the use of the limited resource. For example, if the limited resource is an aircraft maintenance hangar that can host only one airplane at a time, maintenance projects of other airplanes are limited by the availability of the hangar. The resultant schedule of these projects forms a stepped pattern based on the moment in which each project has an airplane in the hangar. The same programming logic applies if the limited resource is a person or department that carries out a specific activity and is unavailable for more than one project (Ricketts, 2010).

Specifically for multi-project management, CCPM proposes the *Scheduling Buffer*. In multi-project environments, each project is programmed in the same way as a single-project environment, but without taking into account the use of resources in other projects. Due to the significant uncertainty of task duration, it is not possible to level all resources across all projects and expect that this initial leveling will remain effective throughout any project duration period. With the purpose of minimizing the need to share resources and to ensure that delays in one project do not affect other projects, the entry of new projects into the system must be controlled. To this end, a *Scheduling Resource* is defined in accordance with the Capacity Restriction Resource of the Drum-Buffer-Rope method or TPC (application of TOC in planning and production control). It is chosen from among the resources that participate in the majority of projects. A specific buffer is defined in each project ahead of the first task to be executed by the Programming Resource, in order to minimize the impact of problems occurring in a given project from the entire project portfolio. This protection is known as the *Scheduling Buffer* (Budd & Cerveny, 2010).

According to Yang & Fu (2014), the method used by CCPM to prepare a multi-project schedule can be summarized in three stages. Firstly, after each project has been individually programmed, the principal constrictions that influence the set of projects are identified. From this point, it is possible to prepare the general schedule, eliminating conflict between the activities that share the use of this resource. This staggering of different project tasks that utilize the same critical resources is equivalent to the leveling of resources carried out to determine the Critical Chain in individual projects.

In the second stage, a *Capacity Constraint Buffer* (CCB) is defined, which ensures the availability of the resource that needs to serve various projects. The third stage involves the definition of the Programming Buffers. These buffers are sized in the same way as the Feeding Buffers and guarantee that restricted resource delays do not have repercussions for later projects. The control of Buffer Management for individual projects is done analogously, monitoring the consumption of the new lungs.

As previously seen, bad multitasking is common in multi-project environments where shared resources are working in various projects in parallel. One solution to drastically reduce bad multitasking in such environments is to simply define a maximum number of open projects, even if this means project freezing (Holt & Boyd, 2010). The reason for this is that, from a certain number of open projects, there is an inverse relationship between the project completion flow and the number of open projects, that is, there is a point at which the greater the number of projects running, the lower the completion rate of these same projects. This inverse relationship potentiates the

effect of bad multitasking, reducing the flow even more, which further increases the quantity of projects in progress. CCPM combats this vicious circle by freezing open projects.

The manager in charge of all projects determines project prioritization, and the freezing of those projects with lower priority. The number of open projects should occupy less than 75% of existing capacity, as this would avoid multitasking without the workload being too small, in such a way that the psychological effects would decrease the rate of project completion. The projects should be sequenced according to a list drawn up by the manager responsible for all projects. It is only when one project is concluded that a new project is opened (or unfrozen) (Herman & Goldratt, 2010).

5 Potential antagonisms and complementary opportunities

In this section the antagonisms of purpose between the PMBOK® Guide and CCPM are presented, as well as the opportunities for complementation between them. This section is based on data collected from the literature review.

5.1 Antagonisms

The principle points of divergence are related to the way the Time Management of a project is viewed. The Guide offers various tasks time estimation techniques, such as the opinion of specialists, analogue and parametric estimates, the PERT (*Program Evaluation and Review Technique*) three-point estimate and reserves analysis. These techniques are based on statistical models regarding information provided by people that, according to the CCPM perspective, skew the data for psychological reasons. This information is not contested, as CCPM proposes. The techniques demonstrated by the Guide are opposed to the way CCPM prepares a schedule, that, as shown, inserts time protection at the end of a project and in non-critical activity chains, and not in individual activities, thereby determining the greatest path of activities based on dependencies between resources and controlling the project through the consumption of buffers.

As previously seen, the Guide proposes several techniques as schedule control and development techniques. Among these are techniques which are in clear opposition to CCPM, such as the critical path method (CPM). CCPM, instead, points to failures in CPM, which would unnecessarily prolong project deadlines, without the counterbalance of an increase in reliability (Rand, 2000).

Another important identified antagonism refers to the fact that while CCPM focuses explicitly on time management, the PMBOK® Guide does not establish any area as critical. This reflects in the performance measures of the project. CCPM expresses measures in relation to schedule progress, such as buffer consumption, for example. The Guide presents performance measures that are prepared and controlled by processes within each PM area. Thus, the PMBOK® Guide, being a compendium of common practices, does not establish a focus on any aspect of project management. It would be the responsibility of the project manager to identify what is critical and to adopt the performance methods and measures considered most appropriate.

5.2 Opportunities for complementation

A potential limitation identified in the PMBOK® Guide refers to the absence of processes that deal specifically with the management of multiple projects, focusing on their peculiarities. The Guide is unassertive in terms of proposals to deal with the impacts that an individual project might have on other projects that an organization can develop and that share its resources. Though dealing with some of the practices inherent in multi-project environments, such as risk management, costs or portfolios, the Guide does not explore specific ways of controlling and measuring performance deadlines in multi-project environments.

CCPM, on the other hand, presents concepts, such as project freezing, staggering projects according to the established programming for a fixed resource and the establishment of the programming buffer, which are focused exclusively on the management of multi projects and could, therefore, be included in the Guide.

Another gap observed in the Guide is the absence of concepts related to the behavior of those involved in a project which is harmful to it. CCPM considers these psychological aspects highly relevant and deals with them explicitly. Concepts such as Student Syndrome, Parkinson's Law and the practice of multitasking, could be integrated into the Guide as practices to be avoided, highlighting the reasons for their emergence.

As CCPM is a focused approach, it concludes by taking as appropriate all the practices which it does not explicitly deal with. In other words, CCPM seems to explicitly consider certain practices inadequate and in need of change. Others are omitted, implicitly treating them as those that can be maintained because they are considered good enough (or that they do not currently limit project performance). In this sense, the Guide could act as a source of models and apt solutions for those areas not encompassed in an implementation of CCPM.

For example, in relation to project integration management, a project manager based in CCPM

would need to promote the start of the project, that is, the initial descriptions of objectives, participants, deadline, budget and other important information. And yet CCPM does not identify a method in this sense. The PMBOK® Guide could complement the implementation, detailing the Project charter creation process for a given project.

In this way, CCPM initiates its methods from a network of previously elaborated activities, without presenting a way to determine the activities required to achieve project objectives. The PMBOK® Guide offers the means to manage the scope of the project. One example is scope planning through the Analytical Project Structure (APS), which breaks the project down to the level of work packets, a set of smaller activities that provides greater ease for management and control.

In addition to Integration Management and project scope, the PMBOK® Guide contributes techniques and tools from other knowledge areas not dealt with directly by CCPM. As previously seen, CCPM does not seem to consider adopted methodological changes necessary for the areas of cost, risk, quality, and acquisitions, in addition to the two already cited. Even though the premise assumed by CCPM is that the search for improved meaning in project time management may provide positive and significant impacts in the other areas concerned with project management, recommendations for such areas of expertise appear to be of great value to CCPM.

6 Field research, results and discussions

A total of six interviews were carried out. Two interviewees are PMPs® (here referred to as interviewees 1 and 2), two interviewees (3 and 4) have experience both with CCPM and with the use of the Guide, and the other interviewees (5 and 6) are CCPM specialists certified by TOCICO. Generally speaking, analyzing the importance given by the interviewees to the knowledge areas of the PMBOK® Guide, there seems to be a certain alignment between the perceptions. The Acquisitions and Quality Management areas were considered by all as not critical for the success of a project. On the contrary, the Scope Management and Human Resources areas were highlighted as important for the success of an enterprise. Thus, distinct qualification or certification (PMP® or TOCICO) did not appear to have significant influence on the relative importance given to these knowledge areas in the Guide.

The view expressed by interviewees 1 and 2 about CCPM is that it collaborates in the process of schedule development and management, aligned therefore to the way that the Guide positions CCPM within its areas of knowledge (Time Management). However, the other interviewees confirmed that CCPM methods and tools extrapolate such knowledge, possibly bringing other contributions to PM practices. For example, an approximation in approach between the Guide and CCPM with regard to communication in projects was suggested. Interviewees 4, 5, and 6 pointed out that CCPM could facilitate the communication process in projects, because it has an easy-to-understand structure and clearer performance measures. The S&T tool was also mentioned as an instrumental aid for communication management in projects. It is worth noting that, in general, the interviewees identified this area as the most limited in the Guide.

The PMBOK® Guide process highlighted as of great importance by those interviewed was that related to managing the expectations of stakeholders in the project. CCPM could collaborate in this process with the Change Management tools based on TOC, such as S&T trees, Layers of Resistance and Criterion of Success. These tool could potentially facilitate the communication of project events, making the objectives of the enterprise and the means to achieve them clearer. Interviewee 6 further stated that project-focused S&T addressed the "Impacts caused by clients and sub-contractors".

Interviewees 1, 3, 4, and 6 also demonstrated discontent with the current way the Human Resources Management area is dealt with in the PMBOK® Guide, singling out the process relating to project team development as most problematic. It was also pointed out that CCPM could also add knowledge to this area, especially when dealing with certain negative behaviors in project environments, such as Student Syndrome and Parkinson's Law. This contribution to the Guide reinforces the gaps raised during the theoretical research.

Interviewees 1, 4, 5 and 6 referred to the area of Time Management as one of the limitations, noticeably in the process of estimating activity duration. These interviewees confirmed that practices focused on the elimination of individual securities, the sequencing of activities according to Critical Chain and the allocation of buffers, are essential for the area. Of these practices, duration estimates with the elimination of individual securities is not cited by the PMBOK® Guide. This point, therefore, could be included in the Guide, along with the behavioral models that justify its use.

Regarding possible CCPM limitations, the interviewees with experience of this method (3, 4 and 6) identified that the way CCPM currently processes projects in multi-project environments requires additional knowledge. The PMBOK® Guide does not offer

a solution for this type of environment. However, PMI publishes other complementary standards on Programming and Portfolio Management which could improve CCPM on this point.

Another opportunity for CCPM complementation pointed out by interviewees 3, 4, 5 and 6 was the use of S&T as an implementation guide. S&T is one of the most recent TOC innovations, therefore being less consolidated that the other concepts of CCPM. As the purpose of S&T is to indicate what is needed to implement a change and communicate that clearly, the Scope Management (formulation of EAP) and the Guide Communications areas could offer complementary models and techniques.

The specialists mentioned the Project Charter preparation as one of the most important processes in the Guide. Even though CCPM emphasizes the importance of *full kit,* it does not recommend a practice similar to drafting the project charter, perhaps because of its focus on time management. Therefore, CCPM applications could use this PMBOK® Guide process as a complement to usual practices.

One area generally highlighted by the interviewees was that of Scope Management. As CCPM does not recommend specific techniques to define the activities necessary to reach project objectives (part of the principle already defined), the Guide's recommendations for this area of knowledge could be incorporated by CCPM.

The opinion of the four CCPM specialists matched with the theoretical research results in regard to the antagonisms shown between part of the practices recommended by the Guide and those contemplated by CCPM, but the problem of coexistence between CCPM and the PERT/CPM method was specifically mentioned. Although the PMBOK® is generic in nature, it could clarify the existing contradictions, justifying their applications on a case-by-case basis and avoiding distortions in their applications.

7 Conclusions

The main objective of this study, based on the survey of basic gaps and premises of both CCPM and the PMBOK® Guide, was to identify points of antagonism between them, as well as opportunities for complementation. It was possible to verify that most of the points raised in the theoretical review were confirmed by the analysis of the questionnaire results.

Even though the presence of CCPM in the PMBOK® Guide expresses an evident synergy, the fact is that a substantial number of the practices contemplated by CCPM are not recommended by the Guide. The interviewees held a similar opinion, including the PMP® specialists, who appear to confirm the perception that CCPM could have been given greater attention by the Guide. It was, for example, pointed out by the CCPM specialists that the Guide contemplated the removal of individual securities proposed by CCPM. Buffer additions are mentioned in the Guide, but that the expected activity durations are overestimated and should be cut, is not reported.

Of the concepts defended by CCPM that could potentially improve the Guide, can be cited: i) the behavioral models, such as Student's Syndrome and Parkinson's Law, could contribute to the area of Human Resources; ii) its methods of programming and project control, including those focused on multi-project environments, which extrapolate the CCPM citations made by the Guide in the area of Time Management; iii) S&T Trees, that could bring interesting contributions to the area of Communications in the Guide; iv) its techniques focused on the management of change and expectations could be of great value if complemented with others already recommended by the Guide.

Some shortcomings in CCPM which could be met by the Guide were also pointed out. One of these refers to the fact that CCPM does not reflection on other areas of knowledge, focusing on Time Management. Techniques linked to project commencement and scope definition were mentioned by specialists as examples of contributions from the Guide to CCPM.

Some antagonisms between the practices recommended by CCPM and by the Guide were also identified. It should be highlighted that the Guide includes techniques with premises opposed to those of CCPM, regarding schedule development and project control. The simple fact that the Guide considers PERT/CPM as a valid method of schedule preparation, already indicates a distancing of the Guide in relation to CCPM. This opposition could be justified by the fact that the Guide is not a closed methodology, encompassing different views without deferring to any of them. CCPM is already a PM methodology, presenting clear stages for its implementation and defending basic premises that must be followed for the success of the project. In any case, by recommending inherently antagonistic practices, without highlighting such antagonisms and therefore without offering ways to address them, the Guide compromises its goal of providing guidelines that support effective project management.

In summary, the study indicates that, just as the practices advocated by CCPM are not sufficient for effective project management, PM practitioners could benefit from CCPM in addition to the little that is mentioned by the Guide. Although the purpose of the PMBOK® Guide is not to give detail to the good practices it recommends, the results of the study

suggest that the Guide could offer more to project managers who have opted to include CCPM methods and tools not yet contemplated, which go beyond the area of Time Management, as well as pointing out certain conceptual antagonisms between them and others reported in the Guide.

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References

Agarwal, A., Borchers, A., & Crane, M. (2009). Managing multiple projects and departmental performance using buffer burn index. *International Journal of Global Management Studies*, 1(3), 1-18.

Barnard, A. (2010). Continuous improvement and auditing. In J. F. Cox III & J. G. Schleier (Eds.), *Theory of constraints handbook* (pp. 403-454). New York: McGraw-Hill.

Budd, C. S., & Cerveny, J. (2010). A critical chain project management primer. In J. F. Cox III & J. G. Schleier (Eds.), *Theory of constraints handbook* (pp. 45-76). New York: McGraw-Hill.

Carvalho, M. M., Lopes, P. V. B. V., & Marzagão, D. S. L. (2013). Gestão de portfólio de projetos: contribuições e tendências da literatura. *Gestão & Produção*, 20(2), 433-454. http://dx.doi.org/10.1590/S0104-530X2013000200013.

Cox, J. F., III., & Schleier, J. G. (2010). *Theory of constraints handbook*. New York: McGraw-Hill.

Dettmer, H. W. (2007). *The logical thinking process: a systems approach to complex problem solving* (2nd ed.). Milwaukee: ASQ Quality Press.

Dinsmore, P. C., & Cabanis-Brewin, J. (2014). *The AMA handbook of Project Management* (4th ed.). New York: AMACOM.

Ghaffari, M., & Emsley, M. W. (2015). Current status and future potential of the research on Critical Chain Project Management. *Surveys in Operations Research and Management Science*, 20(2), 43-54. http://dx.doi.org/10.1016/j.sorms.2015.10.001.

Goldratt, E. M. (1997). *Critical chain*. Great Barrington: North River Press.

Goldratt-Ashlag, E. (2010). The layers of resistance - the buy-in process according to TOC. In J. F. Cox III & J. G. Schleier (Eds.), *Theory of constraints handbook* (pp. 571-585). Great Barrington: North River Press.

Heldman, K. (2013). *PMP: Project Management Professional Exam Study Guide* (7th ed.). USA: Sybex.

Herman, M., & Goldratt, R. (2010). Less is more - applying the flow concepts to sales. In J. F. Cox III & J. G. Schleier (Eds.), *Theory of constraints handbook* (pp. 587-601). New York: McGraw-Hill.

Herroelen, W., & Leus, R. (2001). On the merits and pitfalls of critical chain scheduling. *Journal of Operations Management*, 19(5), 559-577. http://dx.doi.org/10.1016/S0272-6963(01)00054-7.

Holt, J. R., & Boyd, L. H. (2010). Theory of constraints in complex organizations. In J. F. Cox III & J. G. Schleier (Eds.), *Theory of constraints handbook* (pp. 983-1014). New York: McGraw-Hill.

Leach, L. P. (1999). Critical chain project management improves project performance. *Project Management Journal*, 30(2), 39-51. http://dx.doi.org/10.3102/00346543067001043.

Manhães, J. C. S. (2011). *Estruturação da mudança pela teoria das restrições na implementação do gerenciamento de projetos por corrente crítica: estudo de caso de uma companhia de energia* (Dissertação de Mestrado). Universidade Estadual do Norte Fluminense Darcy Ribeiro.

Millhiser, W. P., & Szmerekovsky, J. G. (2012). Teaching critical chain project management: the academic debate and illustrative examples. *INFORMS Transactions on Education*, 12(2), 67-77. http://dx.doi.org/10.1287/ited.1110.0083.

Newbold, R. C. (1998). *Project management in the fast lane: applying the theory of constraints*. Boca Raton: CRC Press.

Project Management Institute – PMI (2008). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)* (Vol. 1). Newton Square: Project Management Institute, Inc.

Project Management Institute – PMI (2013). *A Guide to the Project Management Body of Knowledge (PMBOK® guide)* (5th ed.). Newton Square: Project Management Institute, Inc.

Rand, G. K. (2000). Critical chain: the theory of constraints applied to project management. *International Journal of Project Management*, 18(3), 173-177. http://dx.doi.org/10.1016/S0263-7863(99)00019-8.

Raz, T., Barnes, R., & Dvir, D. (2003). A critical look at critical chain project management. *Project Management Journal*, 34(4), 24-32.

Realization Technologies Inc. (2010). Getting durable results with critical chain - a field report. In J. F. Cox III & J. G. Schleier (Eds.), *Theory of constraints handbook* (pp. 79-100). New York: McGraw-Hill.

Ricketts, J. A. (2010). Theory of constraints in professional, scientific, and technical services. In J. F. Cox III & J. G. Schleier (Eds.), *Theory of constraints handbook* (pp. 859-878). New York: McGraw-Hill.

Robinson, H., & Richards, R. (2010). Critical chain project management: motivation & overview. In *Proceedings of the Aerospace Conference* (pp. 1-10). Big Sky: IEEE.

Yang, S., & Fu, L. (2014). Critical chain and evidence reasoning applied to multi-project resource schedule in automobile R&D process. *International Journal of Project Management*, 32(1), 166-177. http://dx.doi.org/10.1016/j.ijproman.2013.01.010.

Yang, X., & Gao, P. (2011). A quantitative research of the time buffer of Critical Chain Project Management. In *Proceedings of the 2011 International Conference on E-Business and E-Government (ICEE)* (pp. 1-4). USA: IEEE. http://doi.org/10.1109/ICEBEG.2011.5881320.