Journal of Engineering, Project, and Production Management
2019, 9(1), 48-55

The Role of the Knowledge Intermediary in Evangelical Project and Production Management Theories

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Project and Production Management
Received July 18, 2018; revised November 16, 2018; December 17, 2018; accepted December 18, 2018
Available online January 17, 2019

Abstract: Given the creation of different types of knowledge propositions in project and production management, we discuss what we call 'evangelical' propositions and what as knowledge intermediaries our role should be in its dissemination. We examine both proposition accuracy as well as the process by which the proposition was arrived at. We suggest strategies for knowledge intermediaries to adopt in order to achieve balance in evaluating these developments. Further, we support our suggestions by examining the development of the Theory of Constraints (TOC) and Critical Chain Project Management (CCPM) and the debate that has accompanied these, as a case study. The debate relates to how much of the knowledge proposition in these is really new and whether the method of developing the proposition was lacking in some sense. Knowledge intermediaries, those who are expected to play an important role in disseminating knowledge, will be better prepared to deal with similar innovations in a balanced manner, by analyzing the case of TOC/CCPM.

Keywords: Evangelical theory, theory of constraints (TOC), critical chain project management (CCPM), project scheduling, production scheduling.

DOI 10.2478/jeppm-2019-0006

1. Introduction

In the twenty first century, knowledge is being created at an incredible rate. In some cases through knowledge advancement we may discard old ideas. In project scheduling the use of the Beta distribution in the PERT (project evaluation and review techniques) network is a relevant example. It was known that the Beta assumption was not appropriate in many cases, but in a way it was better than not using it because it allowed decision makers to incorporate uncertainty in project schedules. Today since we have more sophisticated mathematical ability and better computer simulation capability we need not use the Beta distribution where it is not appropriate. So we have discarded old propositions.

But in other cases, we also add to existing ideas without discarding them. In project management for example we went from simple Gantt charts to network scheduling. Gantt Charts did not become obsolete, network diagrams just became an additional tool to help us manage projects. One might say that in this case the concept expanded. So the Gantt chart is still a great visual tool to indicate project plan and progress, while the network diagram allows us to determine aspects such as expected completion time, precedence and bottleneck activities.

In this paper we hope to discuss how the knowledge intermediary community should deal with issues where the nature of knowledge advancement is what we define as 'evangelical'. For example did the advancement change a concept such that we had to discard old ideas, or did it just expand it? We focus on the role of the knowledge intermediary in this debate. We define the knowledge intermediary as an entity that deals with knowledge dissemination. This could be a university academic, a leading practitioner, a journal editor, a leading consultant, or a professional society. We illustrate these issues using a case study of the Theory of Constraints (TOC) (Goldratt, 1984) and of Critical Chain Project Management (CCPM) (Goldratt, 1997). Based on the case study we also make some suggestions to manage debates in the future where such 'evangelism' exists.

2. Relevant Aspects of Knowledge Creation: Accuracy and Process

As knowledge intermediaries in management, we know that a proposition is valid only within some assumptions. For example when we use the normal distribution in PERT,

we assume that the Central Limit Theorem applies and that the nominal critical path (identified by having the largest mean) will indeed be longest. If any of these assumptions does not apply then the determination of project length is theoretically not correct. In project and production management, in addition to this theoretical correctness we may have 'practical satisficing'. For example we know that even if we ignore the stochastic nature of activity durations, to find the optimal schedule for a resource constrained project we have to use mathematical programming. If we obtain the optimal solution it will give the 'theoretically accurate' result subject to the assumptions. However if we obtain a heuristic procedure that a practitioner can apply (assuming that this person has no access to the optimal solution), then from a practice perspective, the heuristic solution may be the 'practically satisfactory'. In our opinion, ideally neither should be completely divorced from each other. Theoretical accuracy should have some value in practice and the practical application should use at least some existing theory.

We also believe that in addition to proposition accuracy itself, whether the process by which the proposition was developed is appropriate, is important from a perspective of knowledge development. In other words not only the end but the means also do matter. This is especially important in 'evangelical developments' where there might be a tendency to ignore previous work on the subject. For example ignoring Newton's acknowledgement that we no longer start from zero (Wikipedia.org; Newton, 1676), which is even more valid in the 21st century than it was in the 17th, and not giving credit to previous work would in most cases would indicate deficiency in the process.

3. TOC/CCPM as a Case Study

We believe that the development of TOC and CCPM makes a good case study in the analysis of concept and process accuracy since we see it as an 'evangelical' approach. Evangelism can be described as 'missionary zeal, purpose, or activity' (Dictionary.com, 2018). An evangelist preaches religion believing that his/her religion is better than the alternatives without really having any scientific evidence. This can lead to controversy. Similarly a review of the literature on CCPM and its precursor, the TOC, shows that some academics and practitioners have been evangelical about these two topics, believing that it is better than other process management approaches, without providing the requisite evidence. This does not mean that the proposed concept or process is not valua ble, it just means that there needs to be another side of the debate to establish whether our understanding of a concept has changed, whether it has merely expanded, or whether there is no new concept. In the case of CCPM there has been such a debate, perhaps somewhat less so in the case of TOC. Thus it provides fertile ground to examine an evangelical proposition development in project and production scheduling and management, as well as to examine the role of the knowledge intermediary.

CCPM is based on based on Goldratt's (1984) previous work on the TOC. Consider the following quote, "The Theory of Constraints (TOC) is a new and important expression of management science invented by Dr. Eliyahu M. Goldratt, a scientist, physicist, author educator, and consultant" - Foreward by Thomas B. McMullen, Jr. (Vice President- Education Development for APICS-The Education Society for Resource Management) in Newbold (1998). The debate can be wrapped around this statement. For example:

- How much is new in TOC/CCPM?
- How important is it?
- Is it actually management science?
- In reality is it more educational or more consulting oriented?

These are questions that have been dealt with in the project management and production management literature, often on two sides of the issue. Two decades after Goldratt's (1997) book the *Critical Chain*, discussing CCPM, was published we review the debate but really from the philosophical perspective of proposition accuracy and process correctness in knowledge development.

4. TOC/CCPM and Its Influence

What is CCPM from a project management perspective? Specifically, it considers resource constraints when dealing with and scheduling project tasks. Take an example from Balakrishnan (2009) shown in Fig. 1, showing a critical path method (CPM) network, using an activity-on-node convention, with times in days. The critical path of this project network is shown by a sequence of bold arrows connecting tasks on the path and the time length for the critical path is 46 days.

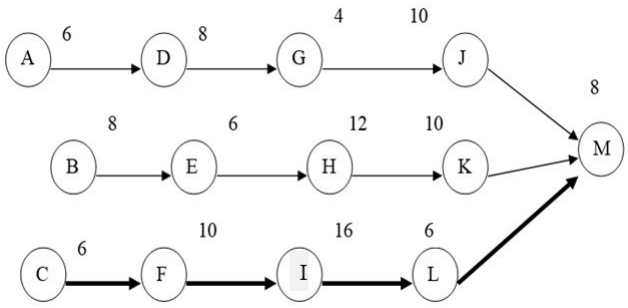

Fig. 1. A CPM network

Slack of 10 days is available for Path ADGJM (i.e., its path time is 10 days less than that of the critical path), whereas path BEHKM has only 2 days of slack (because the path time is 44 days). Let's assume that tasks H and I are performed by employee 1. The CPM model that by nature ignores the usage of resources will assume that the executions of tasks H and I may overlap. However, employee 1 cannot perform both tasks at the same time. This overlap of task executions should not be allowed if resource constraints in project are a consideration. If we assign more than one task to a single employee and require the employer to perform these tasks at the same time period, we should adjust the task lengths to reflect these additional assignments to the employee. Since the order of task H first and task I second gives a shorter resource-constrained project completion time than the reverse order of these two tasks, employee 1 who has been assigned with these two tasks will perform task H and subsequently task I. The revised project network with the critical chain (coined by Goldratt (1997)) is shown in Fig. 2.

In Fig. 2, the critical chain is highlighted in bold. This chain containing the dotted arrow between tasks H and I connects all the tasks along it. Tasks C and F are no longer critical when project scheduling takes the usage of

resources into consideration. Therefore, delays in the completion of tasks C and F (up to 10 days) will not affect task I because task I is directly affected by task H. The length of path BEH is 26 days (i.e., 10 days longer than path CF). So tasks on path BEH become critical (i.e, their actual processing times will directly impact the project completion time). Path ILM is still part of the critical path. Hence, tasks along the critical chain give a sequence of tasks satisfying both technically dependent and resource-usage considerations.

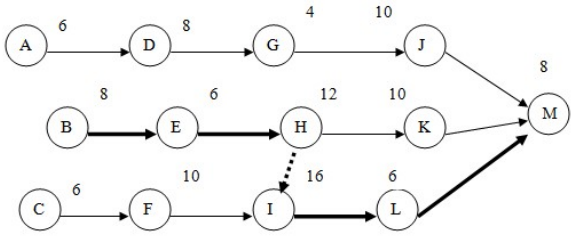

Fig. 2. The critical chain

As mentioned, the basis of CCPM is the TOC, which proposed managing by focusing on the constraints in a system (Goldratt's 1984 TOC book, *The Goal* uses a manufacturing plant as an example). Both physical and non-physical constraints may be considered. For example, machine capacity is a physical constraint while managerial policies such as pricing are a non-physical constraint. TOC/CCPM as a continuous-improvement process is composed of the following five steps:

1) Identify the system constraints.

2) Decide how to exploit the system constraints; i.e., determining how to use the system constraints to maximize the system performance.

3) Subordinate everything else to that decision.

4) Elevate the system constraints (i.e, increasing the right handed sides of the constraints in the Linear Programming - LP sense).

5) Return to Step 1 for further improvement in the system performance if the above steps produce new constraints.

In a manufacturing process the system constraint (bottleneck) may be the slowest machine in the production process while in a project schedule it may be the resource constrained critical path (which CCPM refers to as the 'critical chain'). However in a system, uncertainties may be caused by unexpected machine failure, unreliable delivery, or unanticipated worker absenteeism, etc. So Goldratt (1984) suggests that buffers at key positions in the process, called the constraint buffer (CB) or shipping buffer (SB, for completed products) be used to respond to uncertainties. Both buffers could be in units of inventory or in units of time (particularly in the case of project scheduling). A constraint buffer could be the addition of slack to certain activities while the shipping buffer would be slack added to the project completion time. In the case of manufacturing, items could be produced ahead of actual demand (a time buffer) to provide some slack or it could just be additional inventory available upon demand (shipping buffer). A constraint buffer could be inventory placed ahead of the bottleneck machine to ensure that it is not rendered idle for lack of work.

Cause-and-effect analysis, drum-buffer-rope (DBR), and evaporating cloud, are some examples of continuous improvement tools often used in TOC and CCPM. Early reviews of these techniques and their applications include Rahman (1996) and Herreloen et al. (2002). Recent updated reviews of TOC/CCPM are provided in Raz et al. (2003), Trietsch (2005), Gupta and Boyd (2008). Balakrishnan et al. (2008) discuss the TOC (primarily the drum-buffer-rope method), its influences and its controversies from an academic perspective. Our paper while having some commonality with this paper, is significantly different in focus. We focus on the role of the knowledge intermediary, and the TOC (primarily the critical chain project scheduling method) is used as an example rather than being the focus.

Goldratt, with the support of *APICS* (formerly the American Production and Inventory Control Society), has focused the attention of industry on the importance of process constraints. Although Bock (1962) was probably first to recognize the impact of bottlenecks, Goldratt was the person to translate these complicated bottleneck issues into easily-understood principles for process management.

In the *Critical Chain*, Goldratt (1997) uses DBR concepts for project scheduling, though Casey (2005, p33) and Ash and Pittman (2008), point out that Pitman (1994) had applied TOC principles to project scheduling earlier. Pai and Giridharan (2012) indicate that both CCPM and TOC are often applicable in projects. For example in the mega power plant construction project that they describe in the paper the steel manufacturer used TOC to ensure timely supply of steel in the power plant construction.

Trietsch (2005) demonstrates that resource constrained project schedules are actually forerunners of TOC/CCPM. So what is new? We believe the knowledge creation here is the ability to convert the concept from its theoretical form to a practical one. Resource constrained optimization in the early days of PERT/CPM was not accessible to practitioners (this was true in manufacturing also), thus it remained esoteric. Thus by explaining the notion of exploiting the constraints in the system in a simple manner useable by those in the trenches, Goldratt has certainly contributed to the knowledge expansion. Mabin and Balderstone (2003) discuss actual applications of TOC in practice while Cox's (2014) list includes many applications of CCPM. In India, Larson & Toubro (L&T) an engineering, procurement and construction (EPC) company that is involved in mega projects globally, teaches critical chain in its affiliated institute to train project managers (L&T Institute of Project Management; http://www.lntipm.org).

A survey of 1783 quality management professionals in USA by Adams et al. (2007) appears to reveal that constraint management (TOC) was not seen as a distinct management philosophy, rather it was seen as more narrowly applying to production and inventory management. Lechler et al. (2005) compare the critical chain and critical path approaches and identify the advantages of each. While critical chain is more sophisticated and focuses on system improvement it can also be more difficult to implement. Goldratt (2008) discusses the influence of the Ford and Toyota production systems, (as well as the work of Shewhart (1931) and Deming, (2000)) on DBR and discusses the situations under which these methods are appropriate.

In recent years the concept of theory of constraints has been used to address barriers in knowledge management (Chatterjee, 2014). Eckardt et al. (2015) point out that business simulation games can use inaccurate costing systems which can be disadvantageous when applying the learning to actual situations. They suggest Goldratt's (1984) throughput accounting as a possible method to avoid this error in certain situations. Regarding Goldratt's (1997) critical chain principle, Narasimhan (2018), states "This would be an example where rigor of logical reasoning is high but relevance, in terms of practical application might depend on the individual context and application of the ideas." In other words, project managers would have to customize the principle depending on the nature of the project because what is applicable in a software development project might not be appropriate in a complex project for the design, installation and operation of an off-shore wind farm. Thus Narasimhan (2018) seems to imply that approaches need to be flexible and not 'evangelical'. Pacheco (2014) compares TOC and Six-Sigma and finds overlap between the two. Spender (2014) opines that "Management and organizational theorists seldom mention the last (referring to Goldratts's (1984) TOC) though it is widely applauded by managers." Thus it reflects the critical issues that will be discussed later in this paper. Doyle (2010) discusses the use of in-class critical chain learning simulations.

However as we will discuss later there have been work done by researchers that have attempted to establish TOC as best method in production scheduling and CCPM as the best method in project scheduling which has led to controversies referred to earlier.

5. Lessons for the Knowledge Intermediary

In light of the controversies in TOC/CCPM, what is to be done in the case of evangelical promotion of 'truths' that may be flawed? As a knowledge intermediary community we can try to influence the acceptance of the real knowledge by providing balanced and critical analysis, through our journals, other business publications whether books or magazines, academic and professional conferences, and workshops. Knowledge intermediaries should also be better at getting practitioners to be more critical thinkers. Below we detail six suggestions when evaluating evangelical type propositions.

5.1. Embrace the Value Despite Controversy

One should not ignore the development because of its faults. An interesting observation regarding the evangelical approach (as evidenced by the TOC/CCPM experience) is that the reluctance of proponents to debate may result in backlash on the part of others. The more the proponents of an evangelical development are likely to try to establish their development as the 'truth', and as an alternative for previous development, the more the rest move further away in the opposite direction and believe less and less in any contribution in the development. According to Trietsch (2005), "detractors rarely mention Goldratt in writing". This is not desirable for two reasons in any new development – the valuable contributions are ignored and the shortcomings are not addressed. In contrast the mission of the knowledge intermediary community in analyzing TOC/CCPM should be to put the work in perspective, reject the deficiencies and build positively on the value added.

For example, unlike a typical research approach used by most academicians, Goldratt (1984;1997) uses a novel (story) setting to advocate his ideas in both *The Goal* and *Critical Chain*. This turns out to be appealing and effective in communication. Goldratt's method itself may be considered a new concept in communicating production and project management knowledge in that it has been influenced others to use a similar style (for example, Jacobs and Whybark's (2001) work in Enterprise Resource Planning).

In academia TOC/CCPM has made its impact on both research and teaching, again creating knowledge. However, some may argue that many TOC proponents adopt an 'evangelical' approach and that perhaps they do not attempt to provide an unbiased view of the knowledge. Regardless of the validity of this criticism, we observe that TOC proponents have drawn the research focus on bottleneck issues and that they have created new avenues for sound research. An example of this is the work by Miltenburg (1997). He examines the use of Just-In-Time (JIT), TOC and Material Requirements Planning (MRP) by applying a Markov Chain Model to a simple production line. In addition, with the help of an example of a microelectronics plant, Miltenburg implements TOC process in MRP and successfully shows that TOC and MRP can be combined for better performance. This is a good news for current MRP users, as they will continue to use MRP and enjoy the benefits of TOC at the same time. Similarly Cohen et al. (2004) compare the CCPM to other project scheduling rules and determine there are other rules that are superior to CCPM. So again the questions generated by an evangelical method led to more rigorous research in the area.

The renewed focus on bottlenecks has also benefited us as educators in teaching. The authors, together with any instructors around the globe, emphasize the importance of bottlenecks. While the focus on bottlenecks is the result of experience gained in years of teaching, research, and practice, it is undeniable that the emergence of TOC/CCPM has helped this emphasis become more explicit and more concrete.

It will not be difficult to find local examples where the application of TOC's at least some of the five steps can be a good teaching tool. For example, while many instructors have been implicitly discussing Step 1 (critical path) and Step 4 (crashing), they may do it in a non-integrated silo manner. Further, in many textbooks, the discussion of the critical path and project crashing may be pages removed from each other and may be illustrated with different examples. Thus it is difficult for a student to see the holistic relationship between project scheduling and controlling and improving the process. So incorporating the five step process may improve this understanding. Similarly one can demonstrate the link between LP and TOC/CCPM. Indeed in the authors' opinion, using a single constraint LP, one can use TOC principles to explain intuitively the principle of LP – to leverage resources to maximize or minimize an objective. Also this type of a simple LP problem can used to explain the concept of a shadow price by examining the effect on the objective function when changing the right hand side of the single constraint. Of course one also has to clarify that when there is more than one constraint, TOC can no longer guarantee the optimum.

So regardless of the flaws of a new concept, it has the benefit of forcing us to reevaluate what we do and whether it can be done better not only in one area but perhaps others. This may lead to new knowledge.

5.2. Provide a Balanced Analysis

While this might seem to be obvious given what knowledge communities do, it has been somewhat lacking in the case of TOC/CCPM. The fact that articles still appear implying that TOC/CCPM was the first to focus on system constraints in production and project scheduling is testament to this. Critical debate allows us to establish the actual value of a development.

Simons and Simpson (1997) state "Both Conway's (1997) and Spearman's (1997) comments reflect one of the sources of discomfort academics have long had with Goldratt's ideas; the theory has been appropriated and/or redefined traditional terminology to mean either more specific, more vague or simply different from long standing usage". Therefore it is important to analyse and evaluate different concepts, issues, and applications to bring out a balanced view.

For example, while Ronen and Starr (1990) critiqued TOC theory, they also state "OPT (the first software part of TOC) has done a n important job of translating terms used by professional into day-to-day language. For example, not many people use terms such as "scarce resources" and "non-scarce" ones. Yet we hear more practitioners talking about "bottlenecks" and "non-bottlenecks" ".

With a development such as TOC/CCPM which is different from JIT, total quality management (TQM), or Six Sigma in that it starts from principles rather than from implementation practices at major organizations, it is important for the knowledge intermediary community to critically evaluate it. In JIT, we had the experience of Toyota and in Six Sigma we had the experience of Motorola to evaluate the pitfalls and road map for these processes. With TOC/CCPM, the principles started with OPT in the late 1970s, *The Goal* (Goldratt, 1984) and other books starting in 1984, and culminating with a new focus (on project scheduling), in the *Critical Chain* (Goldratt, 1997). Thus the principles when publicized had not had time to be validated. Given that TOC/CCPM books are written for the practitioner and contain statements that may not have been tested, it is important that knowledge intermediary community attempts to validate or invalidate these statements. For example both *The Goal* (Goldratt, 1984) and The *Critical Chain* (Goldratt, 1997) promote a 100% buffer based on conjecture. In addition to lacking in theoretical basis (Ash and Pittman (2008) call it 'academically unsound'), Herroelen and Leus (2001) in a simulation study show that the suggested figure could be seriously wrong in project scheduling. Furthermore, even if it were possible, it would be wasteful (Trietsch, 2003).

5.3. Emphasize the Tradeoffs between Theoretical Accuracy and Practical Satisficing if Applicable

Since project and production management are applied fields, it is important to address practical versus theory issues. However, Noreen at al. (1995) point out that over-emphasizing the importance of constraints and over-simplifying theory may make TOC practitioners likely forgo improvement that might have been obtained through working on non-constraints. This clearly demonstrates that while simplifying can be useful, oversimplifying may be counterproductive.

In the literature, researchers have identified problems resulting from TOC scheduling approach's oversimplification. To name a few, for instance, TOC does not focus on buffer management (Spearman, 1997), multiple performance measures (Pinedo, 1997), and non-constraints in a dynamic environment (Conway, 1997). Herroelen and Leus (2001) and Herroelen et al. (2002) identify problems due to over-simplification in the CCPM approach. As another example, Askin et al. (1999) show that the TOC dictum 'focus on the constraint' may not always be correct. Notably, TOC/CCPM attempts to manage inherently stochastic problems (including shifting bottlenecks and shifting critical paths) through a deterministic approach. As mentioned earlier Cohen et al. (2004) identify superior approaches to CCPM. Raz et al. (2003) and Trietsch (2005) are other sources of critical analysis of TOC.

Thus while the advantage of the TOC concepts may be in its ability to communicate project scheduling principles effectively, the disadvantage may be that in the pursuit of a practical satisficing, it divorced itself too much from the theoretical knowledge. This may then result in the practical knowledge losing much of its potential value.

5.4. Highlight the Knowledge Generation Process Gaps if Present

As mentioned we believe that in addition to accuracy of the knowledge generated itself, the process of acquiring the knowledge has to be appropriate. As we show from a literature review in this section, this process in the case of TOC/CCPM may have been deficient.

Bottlenecks are not an unfamiliar concept to the professional management science community. For instance, Bock (1962) demonstrates how they are traditionally used to find the optimal solution in mathematical programming, such as LP. Wiest (1964), defines a 'critical chain' like term, 'critical sequence' as part of his work on resource constrained project scheduling, Thus the principles of TOC/CCPM appear not to be an new. Instead, as mentioned, it appears to be true that TOC/CCPM is a refocus on some important aspects (simplifying and communicating) of process management and that TOC/CCPM is presented in an easy to understand manner, i.e., a focus on practical concepts. But as we explain below, the problem appears that TOC/CCPM ignores relevant previous work.

Also as mentioned earlier, perhaps more than other approaches, TOC/CCPM has been an 'evangelical' approach which has affected the tone of academic articles and books written by its proponents, many of whom have presented TOC/CCPM almost as gospel type truth. There seems to be strong effort to project TOC/CCPM as a significant new knowledge and one that is better than others such as JIT, in other words, the 'truth' has changed and one should prefer the TOC/CCPM over previous approaches. Many articles in TOC/CCPM ignore or fail to mention previous or related approaches to managing constraints.

As an example, JIT is different from TOC as it does not use the five-step approach. Based on this observation, the *Critical Chain* argues that TOC is more effective than

JIT (Goldratt, 1997, p. 146-148). Further, TOC criticizes that line stoppages may happen when a workstation goes down, due to lack of buffers in JIT. However in actual JIT execution, Toyota does use buffers to manage and control variability (Spear and Bowen, 1999). Triestch (2003) also shows that concepts prevalent in TOC such as managing material flow, reducing cycle time based on bottleneck (the DBR approach), emphasizing education and training, and changing management attitude form part of JIT, which actually preceded TOC.

To advocate and promote TOC, it also criticises some traditional tools people have been using for a long time. For example, the *Critical Chain* (Goldratt, 1997, p. 69), dismisses optimization. While clearly there are many proposed esoteric optimisation models many examples of applied optimization models, including in production scheduling and project scheduling, exist in practitioner journals like *Interfaces,* (where evidence of the model's use in practice is a precursor for publication). In fact, some articles by TOC proponents, the arguments and claims of which were later found technically flawed, indicate that TOC will produce the same result as LP (for examples of the proposition and critique see Luebbe and Finch, 1992; and Balakrishnan and Cheng, 2000 respectively). According to Spearman (1997), if TOC (always) produced the same result as LP, then TOC's 'greatest contribution' would be to the solution of linear programs. Thus by trying to present previously proven approaches as not true, the 'evangelical' knowledge seeking process in TOC/CCPM is deficient.

Work by Noreen et al. (1995) on TOC indicate that benefits in organizations often arise from the application of a combination of methods, and one of them cannot be isolated as the primary reason. So an 'evangelical' approach could be counter-productive. It could mislead practitioners into questioning the legitimacy of other plausible approaches and accepting TOC as the only one. This could result in practitioners implementing incomplete knowledge, and not achieving the best possible benefit. Thus knowledge intermediaries have to highlight the disadvantages of blind belief in a certain technique by providing a balanced analysis.

5.5. Emphasize the Role of Critical Thinking and Scientific Analysis in Decision Making

One of the mandates of knowledge intermediaries should be to convince the next generation of managers to be more critically oriented. It is important that students and practitioners in the 21st century recognize the importance of informed and scientific analysis in decision making so that they can understand the evaluate new propositions in project and production management in a balanced manner.

For example Goldratt's books do not have any references. This may be acceptable as they are written in the form of novels. However Goldratt (1988) is not a novel and it should be more of a scientific writing. Yet it almost entirely refers to Goldratt's own work. All this might give an impressionable reader that all the ideas discussed in Goldratt (1988) are new. So it imitates a consulting approach rather than scientific analysis which is not consistent with the earlier quote from Newbold.

Knowledge intermediaries should take the lead to ensure that students follow more of a research approach in ensuring that they understand prior and related work, and recognize the importance of the previous work. For example if books on TOC/CCPM are being used in the classroom (whether it is in tertiary institutions or professional workshops), students should also refer to Wiest's (1964, 1967) and Wiest and Levy's (1977) work on resource constrained project scheduling, the websites of different project management software vendors, and Schonberger's (1981) work on project schedule simulation. The practitioner community will then learn for themselves the need to critically evaluate material that they encounter, and not be possibly misled by 'evangelism' or consulting approaches.

In order to practice what we preach, academics should give the due acknowledgement to well-deserving colleagues in their own writing. Unfortunately in some cases they have not kept up the work of their colleagues in the same research community – Ronen and Starr (1990) showed OPT principles were not new – yet in 2014 some textbooks still refer TOC to as a new method. Thus recognition of our colleagues' prior work has been sometimes ignored. For example, we ran across the solutions manual of a textbook that gave a wrong solution to a product mix problem when discussing TOC. This occurs because the problem has multiple binding constraints (bottlenecks), yet the TOC only focused on one bottleneck and gave a heuristic solution. The analogy would be looking at only one critical path when there are multiple. Students using the TOC method would get a solution corresponding to the one in the instructor's manual and erroneously think that they have the correct answer. LP should have been the right method in this case, not TOC. This error is not something we like to see as educators.

This extends to journal and professional business publication editors who should ensure that work published is rigorous. A reputed journal a few years ago published an article that gave Goldratt credit for stating first that constraints determine the performance of a system. The article has seven references in the bibliography of which four are Goldratt books, two are other TOC references, and one is a reference to a definition in a dictionary. It is rather difficult for an article citing almost exclusively TOC writing to give a balanced view. Thus those new to TOC may feel that its principles are all novel. In this age of the Internet that provides a rich set of published material, we should expect the writers to present different sides of developments. Otherwise we risk more developments with an 'evangelical' type approaches and flawed propositions.

Spearman (1997) points out that when he was at a TOC seminar for professionals at the A.Y. Goldratt Institute and offered a critical assessment of some of the TOC principles, his comments were not well-received by those in attendance ("…only served to convince my industrial counterparts that academics were indeed useless"). This example clearly indicates an important divergence between practitioners and academics. Although we, as an academicians, do not pay enough attention to implementation, we view critical analysis of concepts and methods as an important part of our job. By the same token, practitioners on the project floor may focus more on implementation perhaps without too much attention on need for prior testing.

With the internet and various other technology tools, the knowledge intermediary community has various tools

to disseminate knowledge, skills, and critical thinking to audiences. For exam ple the results of variation on project buffers, and process improvement, need not be just academic concepts anymore. These can be brought to the classroom and professionals in a meaningful way.

5.6. Encourage Debate in the Field

The *Critical Chain* (Goldratt, 1997) drew some debate in the field with critiques appearing in the PMI's (Project Management Institute) journal, the *Project Management Journal*, and its magazine the *PM Network*. Further there were online discussion groups (Herroelen et al., 2002). Without such balanced debate we risk people reading the *Critical Chain* (Goldratt, 1997) not recognizing that the concepts date back at least to the 1960s and that the contribution relates to 'practical satisficing' rather than a new theory. As stated, expanded concepts can be very useful. However the expansion should credit previous work.

Interestingly, *PM Network*, has taken a unbiased stance on CCPM (Herroelen et al., 2002) whereas *APICS* has in general been a proponent of TOC from the very beginning, as seen from the Newbold quote earlier. Perhaps this is another aspect we should work on as knowledge intermediaries – getting practitioner knowledge organizations to critically evaluate the new concept and technique before making an institutional endorsement decision.

6. Conclusion

Many innovations have occurred in the project and production management field. One of the more intriguing ones is TOC/CCPM. Its development has been different from many of the other new concepts or methods proposed in the field. Clearly TOC/CCPM has been successful in facilitating professionals to implement better process management practices. For knowledge intermediaries this illustrates the use of communication and simplification in dissemination in helping practitioners understand and implement developments. However, by oversimplifying, TOC/CCPM can lead to poorer performance (Trietsch, 2003). Secondly TOC/CCPM has perhaps been lacking in the development process sphere. For knowledge intermediaries this highlights the importance of their role as unbiased managers of knowledge creation.

In this paper, we used TOC/CCPM as a case study to understand new developments in the field and how a similar situation might be handled in the future from a knowledge intermediary perspective. Both innovators and those who later critique, do research, teach, and implement the innovations should be able to benefit from these lessons.

Acknowledgements

The author would like to thank Professor Dan Trietsch of the College of Engineering, American University of Armenia for his helpful sugg estions. This research has been partially supported by a GRF grant from Research Grant Council of Hong Kong SAR (Grant No. 14615015).

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