The Theory of Constraints in Academia: Its Evolution, Influence, Controversies, and Lessons

Jaydeep Balakrishnan
Operations Management Area
Haskayne School of Business, University of Calgary
Calgary, Alberta T2N1N4, CANADA
Email: Jaydeep.Balakrishnan@haskayne.ucalgary.ca

Chun Hung Cheng
Department of Systems Engineering and Engineering Management,
The Chinese University of Hong Kong
Shatin, Hong Kong
Ph: +852 2609 8322  Fax: +852 2603 5505
Email: chcheng@se.cuhk.edu.hk

Dan Trietsch
College of Engineering
American University of Armenia
40 Marshal Baghramian Avenue
Yerevan, Armenia 0019
Email: dan.trietsch@gmail.com


1 Author for correspondence
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Abstract:
The ‘Theory of Constraints’ (TOC)—more appropriately described as Management by Constraints (MBC)—is a case of a development that has raised an interesting debate in the field of Operations Management. Points of debate include how much of TOC is a ‘refocus’, how effective it has been, and how it relates and compares to other developments in Operations Management.

In this paper, we focus on what lessons academics may learn about disseminating controversial developments from the debate that has accompanied TOC. With the tremendous information explosion, we may see more such controversial developments. Therefore examining the case of TOC may help academics, the people who are expected to play an important role in dissemination, to deal with similar developments in the future, in a balanced and critical manner.
Introduction

It has been more than twenty five years since the publication of the first TOC related material (Goldratt, 1980). In the interim there have many articles and books that have dealt with various aspects of TOC – mostly with theory and application, some about caveats. Thus we feel that it is an appropriate time for academics in Operations Management to debate its influence, since that is one of the mandates of our profession – to evaluate new developments and distil them so that we can educate the new generation of managers and students to manage processes better.

TOC is interesting to analyze for two reasons. First, unlike Just-In-Time (JIT), Materials Requirements Planning (MRP), Total Quality Management (TQM) or Six Sigma, when the first TOC related book, *The Goal* was published (Goldratt, 1984), it did not have a significant history of implementation. Second, it has been sometimes promoted quite strongly as a complete alternative to JIT, MRP and TQM if one includes all TOC concepts.

On the one hand, to a degree, TOC has been successful in getting the greater practitioner community to implement better management practices. For academics this illustrates the importance of communication and simplification in getting practitioners to implement developments. On the other hand, by oversimplifying, TOC can lead to detrimental performance; e.g., over-emphasizing a single bottleneck, and thus losing opportunities to increase net throughput by better balance (Trietsch, 2005a). For academics this highlights the importance of our role as critics and guardians. Society does not expect us to applaud
every new development, rather it expects us to provide balance and corrective feedback where necessary.

Our paper is divided as follows. First we describe the evolution of TOC. Then we identify what we believe have been the influential aspects of TOC with examples of how TOC principles can be used in our teaching. Then we discuss the controversial aspects of TOC. Following this we integrate this paper by discussing issues regarding TOC that we feel has provided lessons to us as academicians. The final section concludes the paper.

The Evolution of TOC

Goldratt along with the help of APICS-The Association for Operations Management (formerly the American Production and Inventory Control Society) has been successful in re-emphasizing the importance of process bottlenecks. While the role of bottlenecks in process management has been recognized for a long time (Bock, 1962), Goldratt has been successful in translating these bottleneck issues into principles that can be understood by any audience. Arguably, he had done so by gross oversimplification, but there is no question that he had done so effectively.

Watson et al. (2007) in a recent review of the evolution of TOC break up TOC into five evolutionary stages

1. The Optimized Production Technology (OPT) stage (circa 1979-1984)
2. The Goal and The Race stage – OPT as a continuous improvement philosophy (circa 1984-1990)
5. The Critical Chain stage – TOC applied to Project Management (post 1997)
OPT was scheduling algorithm introduced in 1980 (Stage 1). This algorithm scheduled resources based on bottleneck identification. Goldratt (1988b) and Bond (1993) provide detailed explanations of the algorithm and the thinking behind it. According to Aggarwal (1985) the OPT algorithm (with a price tag of about $2 million) was being used by over 100 companies at that time. It appears though that OPT was not a success (Noreen, 1995; Pinedo, 1997) and after investigating implementation failures, Goldratt felt that the lack of understanding of the OPT Methodology was contributing to its failure (Watson et al., 2007). Thus he proceeded to publicize the nine principles of OPT as follows

1. Balance the flow, not the capacity (drum-buffer-rope system).
2. Utilization of a non bottleneck is determined by a constraint in the system (a bottleneck).
3. Utilization and activation of an input are not the same. Running a non-bottleneck machine at its capacity (activation) only produces unnecessary inventory.
4. Any loss in output at a bottleneck translates into a loss for the entire system.
5. Productivity gain attempts should be first focus on bottlenecks first since bottlenecks constrain the system.
6. Bottlenecks determine the throughput (product completion rate) and inventory levels.
7. For optimization, transfer batches may not equal process batches. For example if a batch contains 100 units, it may be useful to transfer partial batches to speed throughput or to maintain the buffer.
8. Following up on the previous point, the size of the process batches through the system should not be fixed.
9. Schedules should be established after evaluating all constraints simultaneously.

Even after the publication of these principles he did not see much practitioner interest. So Goldratt then used an innovative method to disseminate his ideas. In 1984 along with Jeff Cox he wrote the Goal (Goldratt and Cox, 1984), a novel about production management in which he distilled the OPT ideas into a five step continuous improvement process (Stage 2). This process advocates system management by focusing on the constraints in
the system. These constraints may be physical such as machine capacity, or it may be some management policies such as pricing. The five step process is as follows:

1) Identify the system constraints.
2) Decide how to exploit the system constraints; i.e., maximize the performance of the system given the constraints identified in Step 1.
3) Subordinate everything else to that decision.
4) Elevate the system constraints
5) Go back to step 1 for improvement if the previous steps result in new constraints.

Several techniques such as drum-buffer-rope (DBR), explained in *The Race* (Goldratt and Fox, 1986), evaporating cloud, and cause-and-effect analysis are used in TOC process of continuous improvement. Some of these such as the evaporating cloud and cause-and-effect diagrams came later in the evolution (Stage 4) as will be explained later. Rahman (1996) provides a detailed review of TOC literature and applications to various business problems.

From an Operations Management perspective the DBR scheduling method is an important aspect of TOC. DBR is illustrated using Figure 1.

![Figure 1: Drum-Buffer-Rope Scheduling](image-url)
In TOC, the slowest machine (Machine 2 in the example in Figure 1) is the \textit{drum}, (the constraint or bottleneck) since it constrains the system output. In order to prevent inventory from piling up the system should run at the drumbeat. This is analogous to a band marching to the beat of the drummers. In the example, the drum beat is 5 units an hour, the rate of the slowest machine. Thus no inventory will pile up if the system produces at the rate of 5 units an hour (drumbeat) and 5 units will come out of Machine 3 every hour. This is the ideal situation. Since each unit of product is processed by all three machines, these machines are linked by a virtual \textit{rope}. Machine linked by such a rope run should all at the drum beat.

However in systems, there are uncertainties. For example machines may break down, the supplier may not deliver on time, workers may be absent and so on. As shown in Figure 1, to avoid the shutdown of Machine 2 (the bottleneck) and resulting lost production due to uncertainty in supply when the line runs at the drum rate of 5 units per hour, we maintain some inventory in front of the drum machine. This called the \textit{constraint buffer} (CB). TOC also suggests a \textit{shipping buffer} (SB) of finished products to respond to demand uncertainty. Both buffers could be in units of inventory or in units of time, i.e., units are completed before they are needed (a time buffer) so that there is some slack.

Goldratt also introduced a certification program in TOC called the Jonah Program (http://www.goldratt.com/index.html) through which participants trained in TOC could get a ‘Jonah’ designation.
In Stage 3, Goldratt focused on the overhaul of cost accounting. Traditional cost accounting methods were seen as an impediment to the implementation of TOC since they viewed idle machines as a loss of productivity. Thus there was a lack of focus on bottleneck issues in traditional accounting. On the other hand TOC sees activation of non-bottleneck machines as producing unnecessary inventory. So Goldratt focused on the overhaul (Goldratt, 1983, 1988a; 1990). This included the book, *The Haystack Syndrome* (Goldratt, 1990). Earlier Goldratt and Cox (1984) had introduced three performance measures, Throughput (T), inventory (I) and operating expense (OE). The TOC accounting method was called Throughput Accounting.

The contribution per constraint minute (CPCM) criterion used in TOC is an important aspect of throughput accounting. The CPCM is the contribution generated when a bottleneck resource contributes one minute to the processing of a product. This is used to determine the priority of products to be made or services to be provided in a system. In TOC the bottleneck resource is the one that has the most utilization when market demand is assumed satisfied. Thus instead of using traditional accounting measures of profitability, throughput accounting uses the CPCM measure.

In Stage 4, starting in 1994, Goldratt published another novel, *It’s Not Luck*. Here he introduced Thinking Processes (TP). TP are problem solution tools basically using cause-and-effect diagrams (Rahman, 1998). The TP asks three questions: The first one is ‘what to change?’ The objective is to identify the core problems and uses a tool called Current Reality Tree (CRT). The second question is ‘what to change to?’. The objective in this case is to develop practical solutions and uses a tool called Future Reality Tree (FRT).
The third question is ‘how to effect the change?’ and uses tools such as prerequisite tree (PRT), transition tree (TT), and evaporating cloud (EC). Related to this in 2002, Goldratt et al., discuss the strategy and tactics tree (STT) which is a graphic depiction of the hierarchical relationship between strategies and tactics. Clearly there is a strong relationship between TP and process improvement tools associated with JIT, TQM, and process reengineering (Watson et al., 2007). In addition Watson et al. suggest that TP could be used in conjunction with the others.

In 1997, in the fifth stage of the evolution of TOC, Goldratt applied the principles of TOC to project management in a novel called Critical Chain (Goldratt 1997). DBR concepts are used for project scheduling. The critical chain is the resource constrained critical path (the bottleneck). The project is protected by the time based project buffer, which is conceptually similar to a shipping buffer. A non-critical path in the network that feeds into the critical chain activity has a feeding buffer so that delays in non critical paths do not delay the critical chain. Resources could have some slack capacity or have a time buffer so that it is ready to work on the critical chain when needed. TP are also used in the Critical Chain method.

**Influence of TOC**

Most scholars would agree that TOC with all its flaws had taught us a thing or two about reevaluating topics ourselves and how to communicate.

For example Morton and Pentico (1993), who discuss OPT in their textbook on scheduling, state “Advantages of OPT include clever, intuitive, approximate solutions to
large mathematical programming problems and a strong focus on understanding critical bottlenecks. Weaknesses include only a fair user interface and database. In addition the system seems to have no capability to do reactive scheduling without resolving the full model, which is not practical in real time”. Thus weaknesses exist but the strong points are worth emulating.

In industry clearly many organizations have benefited from TOC, whether in concert with other philosophies such as JIT and TQM or alone (APICS-The Association for Operations Management has played an important role in popularising TOC. With over 50000 members, it has proved to be an excellent avenue for the application of TOC principles). Goldratt’s method of using a novel (story) setting appears to be an effective and interesting way of concept communication. This by itself may be considered a development in academia in that it has been has influenced others to use a similar style (see Jacobs and Whybark’s (2001) work in Enterprise Resource Planning).

Perhaps the fact that developments in OM are unlike that of medicine affords the luxury of imperfect applications. In medicine a flawed treatment can be fatal and thus extensive testing needs to be done before one is approved. For companies that are ineffectively managing their operations, principles that they can understand (like TOC) but that may have shortcoming can help them get started. As Trietsch (2005a) points out, in practice they learn quickly that TOC has to be modified because of some of the drawbacks. But the bottom line is that perhaps for those on the shopfloor many of whom may not have higher education something simple that they can comprehend to get started may be the
best thing. However, as stated, oversimplifying can sometimes be counterproductive. Thus the trick is to ensure that in implementation the flaws are removed as much as possible – through re-education. This is where critical analysis by academics can help.

In academia TOC has had an important influence on both research and teaching. Of course one may argue that many of the articles on TOC have been written by its proponents and perhaps may not present a balanced view. Regardless of this argument we believe it is fair to say that it has rejuvenated the interest in bottleneck issues research and introduced new avenues for sound research. An example of this would be the article by Miltenburg (1997) where a simple production line is evaluated using a Markov chain model which provides insight into the uses of JIT, TOC and MRP. Miltenburg describes a method to embed TOC in MRP using an illustrative example from a microelectronics plant. The intent is to show that current MRP users need not replace their MRP with TOC – they can combine both for better performance.

The renewed focus on bottlenecks has also been useful in teaching. Many instructors now explicitly discuss the influence of bottlenecks, including the authors. In fact one of the authors had an EMBA student tell him “Your emphasis on bottlenecks has me always looking for bottlenecks in situations”. While this emphasis has been a result of experience gained in years of teaching and research, there is no doubt the emergence of TOC has helped the emphasis become more explicit.
Many of us have been teaching these concepts in many different settings but the five steps of TOC perhaps crystalize general principles for what we do in the different areas. For example consider project scheduling. Below we discuss how the five steps might be discussed in an introductory OM class on project scheduling (adapted from Trietsch, 2005b):

1) **Identify the system constraints**: This would involve calculating the critical path. One might discuss the fact (using the capabilities of software such as MS Project) that in practice we may need to calculate the resource constrained critical path.

2) **Decide how to exploit the system constraints**: Focus attention on the critical path to ensure that there is no delay.

3) **Subordinate everything else to that decision**: Activities with slack can be allowed some delay but not to the extent that they are too likely to become critical.

4) **Elevate the system constraints**: Crash the project if necessary.

5) **Go back to step 1 for improvement if the previous steps result in new constraints**: During crashing critical paths can change. Also one may use simulation packages such as CPSIM (Piper, 2000, updated version based on software PLANETS II (Harvard Business School, 1974)) or mathematically through PERT, to illustrate in class how critical paths change due to time uncertainties and value of a buffer.

We can of course make this more or less sophisticated as we deem necessary. In any case it is clear that we have been doing for years what TOC later stressed. However note that usually calculating the critical path and crashing may appear many pages removed from each other. Thus the student may not get an overall picture of the project scheduling and controlling process. Summarizing the project scheduling process using the five steps at the end of the instruction may increase the understanding of students significantly.
Similarly, Spearman (1997) indicates that the questions raised by Goldratt would be useful when discussing assembly line balancing.

Herein perhaps lies the value of a refocusing theory whether flawed or not. It causes us to reevaluate what we do and whether it can be done better not only in one area but perhaps others.

Take LP, where Ronen and Starr have discussed the similarities between it and TOC. Traditionally LP is introduced using a two-variable, few-constraints problem solved graphically. It is not clear that students get the overall principles of what is happening with this approach. In the authors’ opinion the process of LP can be better understood by students if a two variable, one constraint problem is introduced and the five step process is applied. Then the well established ‘bang for buck’ principle (called the CPCM in TOC) can be used to determine the optimal decision. Increasing the right hand side of the only constraint (elevating it) teaches the concept of shadow price in a simple manner. Then of course it can be discussed that with multiple constraints, it is not as simple to use the the ‘bang for buck’ principle. The CPCM will not necessarily give the optimal solution and so a process like the simplex is required. On the one hand, a different way of teaching concepts can be used because of a refocusing development. On the other hand, this is not new ground; e.g., Bock (1962) suggested all these more two generations ago.

**The Controversies**

The controversial aspects of TOC are illustrated by Simons and Simpson (1997b) reacting to comments on the issues raised by Conway (1997) and Spearman (1997) about
Simons and Simpson (1997a). Simons and Simpson (1997b) state “Both Spearman’s and Conway’s 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”. Thus it is clear that TOC is a topic where academics are likely to have strong views. Therefore it is critically important to debate different issues to bring balance.

Other problems identified in the TOC scheduling approach due to oversimplification include the lack of focus on non constraints which may become constraints in a dynamic environment (Conway, 1997), lack of focus on multiple performance measures (Pinedo, 1997) and lack of guidance on buffer management (Spearman, 1997). Problems due to over-simplification in the Critical Chain approach can be found in Herreloen et al. (2001, 2002). On the shortcoming of TOC approach to project scheduling, Goldratt’s answer was ‘it works’ (Cabanis-Brewin, 1999). While this may convince practitioners, as academics we should certainly not accept such an argument. For recent critical reviews of TOC, see Herreloen et al. (2002), Raz et al. (2003), and Trietsch (2005b).

Perhaps more than other approaches, TOC has had a ‘gospel’ approach which has affected the tone of academic articles and books. We define a gospel approach as one in which an idea is proposed with a subsequent tendency to regard this idea as correct without any critical review. Ideas are often expressed in black and white (over simplified).
In our opinion many proponents have presented TOC almost as gospel. There seems to be strong effort to project TOC as a significant new development and one that is better than others such as JIT. It also oversimplifies principles by suggesting black and white approaches – for example by suggesting a 100% buffer protection. Many articles discussing TOC do not discuss previous or related approaches to managing constraints. As academics our mandate is to avoid such approaches to new development. Rather our mandate is to critically evaluate these developments.

For example, Ronen and Starr (1990) showed the isomorphism of Management Science/Operations Research Techniques (MS/OR) techniques and TOC. Since MS/OR techniques of Linear Programming (LP), Queueing, and Simulation are much older, the article clearly implied that TOC was more of a refocusing than a new development. They pointed out the OPT software started out with the well known Pareto analysis (first used in inventory analysis at Ford Motor Company in the 1940s). Thus the primary contribution of TOC appears to be in the successful communication of the importance of bottlenecks, managing material flow reducing cycle time based on this (the DBR approach) and the emphasis on education, training, and focus of changing management attitude. Triestch (2005a) points out that these aspects form part of JIT, which preceded TOC.

Similarly Boyd and Cox (2002) claim that throughput accounting using CPCM consistently produces optimal decisions. However earlier, Balakrishnan and Cheng
(2000) had showed that this is not true. The CPCM method only accounts for one constraint at a time and if there are multiple binding constraints then the CPCM is a heuristic method not an optimal one. Yet TOC literature often gives the impression that CPCM is also optimal.

With regard to over-simplification tendencies in TOC, Noreen at al. point out “that in its desire to emphasize the importance of constraints, TOC is likely to forgo improvement that might be possible through the management of non-constraints. This illustrates while simplifying is useful, oversimplifying is counter productive.

Similar to TOC in manufacturing, the discussion of application of TOC in project management illustrates some of the advantages and problems with manner in which TOC developments have been portrayed. For example Trietsch (2005b) demonstrates, that the traditional project management approaches PERT/CPM are actually MBC forerunners of TOC, so by turning around and applying TOC to projects arguably Goldratt created a misleading impression as if MBC was not well-known in that field.

In the Critical Chain (p 146-148), Goldratt implies that JIT is not as effective as TOC since it does not follow the five steps. He implies that lack of buffer will result in the line stoppages when a workstation goes down. Clearly this ignores the continuous improvement focus of JIT and the buffers built into the system both as kanban allowances and as capacity cushions. Reduction in the buffer is contingent on the reduction in variability. Toyota uses buffers in case of variability (Spear and Bowen, 1999). Again, these include inventory buffers (controlled by kanbans) and capacity buffers.
To promote TOC, Goldratt also criticises some of the effective tools that have been used for decades in business. For example, in the *Critical Chain* (p69) Goldratt states “One thing I hate passionately is optimization problems. There are so many articles about these cases, all with involved mathematical models, all so tough and time consuming to read. And from my experience, all have little practical use”. While there is no doubt that there are many optimisation models proposed but not used, journals such as *Interfaces* where numerous examples of optimization models (including in scheduling) have saved billions of dollars over the years can hardly be described as ‘of little practical use’. (In fact there have been technically flawed articles that have tried to prove that TOC would provide the same result as LP and more information. According to Spearman (1997) if this were true then “Goldratt’s greatest contribution would be to the solution of linear programs”.)

There have been other studies that have attempted to establish TOC as the preferred technique through simulation and other means. Again however, the evidence in practice does not support this ‘gospel’ or marketing view. Booth (1988) and Reimer (1991) discuss implementation of JIT and TOC jointly in factories. The study by Noreen et al. of six companies using TOC also showed that three also used JIT and TQM. Thus a gospel approach could mislead practitioners into rejecting other plausible approaches and accepting the way of the developers and proponents of the theory as the only one. This could result in practitioners implementing flawed theories. This clearly should be anathema to academics.
Spearman (1997) describes his attendance at a TOC seminar for executives at the A.Y. Goldratt Institute. His questioning of some of the principles was not appreciated by the other industry executives (“…only served to convince my industrial counterparts that academics were indeed useless”) or by Goldratt himself. In addition the seminar created the impression that TOC gave the optimal answer to the product mix problem. This illustrates the reluctance on the part of proponents of gospel or marketing type approaches to debate the theory. This illustrates the pivotal role of academics in critically evaluating new theories and developments. Organizations with software packages and training institutes as in the case of TOC can have consulting focus and thus can have bias. We discuss the role of academicians in disseminating developments in the next section.

The Role of Academicians in Disseminating New Developments

First, we feel that it is important that we promote genealogy in research, teaching, and presentations. With access to internet based databases, this has become more and more feasible.

For example Goldratt’s books do not have any references, ostensibly because they are written in the form of novels. However Goldratt (1988) is not a novel and yet its reference list is devoted almost entirely to Goldratt’s own work. All this might give the uninformed reader the impression that all the ideas involved are new, which is not what we as academics should promote. We should ensure readers recognize the importance of prior and related work, and that other contributors are recognized.
We would not accept term papers from students that use existing ideas without providing sources, so why should we not apply the same standards to ourselves? Whether it is in TOC or other fields, we should encourage the use of genealogy. Dissemination should be based on the principle that we cannot accept plagiarism. Otherwise we risk perpetuating myths. This applies to any development. JIT and Six Sigma use the concepts from Henry Ford, Shewart, and Deming and students and scholars of the field should know that.

For example if we are using books on TOC in the class, we should require students to read topics such as kanban or jidoka. If they have taken LP already, ask them to compare the five steps of TOC to LP. Ask students to glance through Interfaces for benefits that companies applying LP have experienced (recall that in page 69 of the Critical Chain, Goldratt expresses his disdain for optimisation). For example, when one of the authors introduced TOC in a second year MBA production planning class to students who had already briefly been introduced to TOC and LP in the first year, he also showed the similarity of the five steps of TOC to LP. Later one of the students in class remarked “I did not realize when we first studied TOC that it was similar to the LP process”.

In addition to perhaps not realizing the LP can help in TOC (an instance of integration of different topics that one studies), the student may have credited Goldratt with a new improvement philosophy. Would this have been fair to Dantzig, Ohno, or Deming?

Similarly if the Critical Chain is being used in class ask students to research Wiest’s (1967), Wiest and Levy’s (1977), and Stinson et al’s. (1978, where they define a ‘critical
chain like term, ‘critical sequence’) work on resource constrained project scheduling, the websites different project management software vendors, and Schonberger’s (1981) work on project schedule simulation. They can also be encouraged to visit the informative internet discussion and other sites.

Students will learn for themselves the need to critically evaluate material that they encounter, and not be misled by marketing hype and exaggeration. This can lead to productive discussions about the difference between consulting approaches and critical approaches. It will also be fair to our colleagues who have contributed to developments in the field. They deserve the recognition.

We should be doing this in our own writing. Unfortunately in some cases we don’t seem to be reading the work of our colleagues – in 1990 Ronen and Starr showed OPT principles were not new – yet in 2008 there are textbooks that discuss TOC without discussing that it is more of a refocusing than the development of something new. In fact the authors even know of one textbook where the instructor’s manual provided the wrong answer to a product mix problem in the TOC section. This occurs because the problem has multiple binding constraints and the CPCM method picks the wrong corner point in the solution space. Note that the student doing the TOC method would get the answer in the instructor’s manual and think that they have the right solution.
When discussing the accounting theories within TOC ask them to compare it to work by Kaplan (1984) who has done seminal work in identifying outdated accounting practices that adversely affect manufacturing.

Perhaps we should be doing a better job on insisting on reference to related lines of research in reviewing papers and editing journals. A recent article on TOC that appeared in a respectable journal implies that Goldratt was the first to state that constraints determine the performance of a system. The article has seven references in the bibliography. Four are Goldratt books and two are other TOC references. The final one is a reference to a definition in a dictionary. Needless to say it cannot be much of a balanced view and the reader will leave with impression that TOC principles were indeed all new. A similar impression is created by Goldratt (1988), even though clearly it is not a novel and should have adhered to academic standards. In this age of internet access to published material we should require writers to present different sides of developments. Otherwise we risk more developments with a ‘gospel’ type approach and consulting disguised as innovative material.

Second, academics also need to provide critical reviews of new developments in practitioner oriented journals, magazines of practitioner societies, and practitioner meetings and conferences. A balanced view can provided with practical alternatives such that the readers can avoid the ‘gospel’ trap. This does seem to have happened in the case of the Critical Chain, where critical reviews have appeared in the Project Management Journal, and in PM Network, both publications of the Project Management Institute
Further there are internet discussion groups on the subject (Herroelen et al., 2002). If we don’t do this we could see more instances of concepts such as resource constrained PERT/CPM (that dates back at least to Kelley, 1963) partially reborn as ‘critical chain’, without anybody realizing that it is a rebirth. The issue in academia should not be the rebirth or ‘refocus’. As stated ‘refocus’ theories can be very useful. However the rebirth should credit previous births.

Interestingly *PM Network*, the magazine of the PMI, has taken a neutral stance on Critical Chain Project Management (Herroelen et al., 2002) whereas *APICS* has in general been a proponent of TOC from the very beginning. Perhaps this is another aspect we should work on – getting practitioner societies to take critical views before making an endorsement decisions.

Spearman’s (1997) negative experience with practitioners when he raised critical questions at a TOC seminar indicates an important disconnect between managers and academics. We view critical analysis (some might argue without enough focus on implementation) as an important part of our job while managers on the shop floor appear to focus on implementation perhaps without too much focus on need for prior testing.

Third even if we feel that a development is flawed, simplistic, or follows a gospel approach, we should resist the urge to reject the entire development as being of no value. As we have mentioned TOC with all its faults, on the whole has been a very positive
development. Our objective should be to be a fair judge – we should not be unbashed fans nor should we be blind opponents.

Fourth, we should be investigating ways to integrate new developments with existing ones and communicating these innovations to practitioners successfully. In the beginning of the 21st century we have the ability better than ever before to communicate what we know to students, whether they are undergraduates, graduates, executives, or shop floor workers. With computer based tools such as spreadsheets, VBA and graphical packages, spreadsheet add-in packages, decision analysis software, cases, and experiential exercises, it is more convenient than ever to teach concepts in an interactive and integrated way. The use of a particular tool may of course depend on the audience. This will ensure that we do indeed communicate knowledge and the value of critical thinking to students. For example the results of variation on buffers, the dependence between different parts of system, and process improvement, need not be esoteric concepts anymore. These can be brought to the classroom in a meaningful way.

For example consider the use of queueing theory to enhance the concept TOC buffers and the use of TOC concepts in process improvement through simulation (for a recent example see Cox and Walker’s (2004) manual simulation exercise on designing assembly lines. This exercise uses kanban and drum-buffer-rope techniques.). This will give students an understanding of the integrated and incremental nature of knowledge development and avoid falling into the ‘gospel’ trap. We should also be encouraging
them to look for related and prior developments whenever we introduce developments such as TOC.

Fortunately, in academia, there is much more of an emphasis today on experiential learning. It has probably been helped by the explosion in executive education in business where necessarily the focus has had to be on the practical. Thus the direction seems to be a positive one in that we are making better efforts to communicate what we know. Societies such as the Institute for Operations Research and Management Sciences (INFORMS) and the Decision Sciences Institute (DSI) have increased their focus on effective teaching including through the launch of new journals dedicated to pedagogical improvements. In addition INFORMS has a special interest group on education that has put a lot of focus into the use of spreadsheets for effective teaching and the DSI has an annual innovative education competition. Efforts such as this will help us as educators to promote critical thought in students, at all levels. This will go a long way in ensuring that the next generation of managers will develop the skills to critically analyze developments they may encounter in the future, or at least recognize that a critical analysis is necessary.

**Conclusion**

The Operations Management field has seen many developments. One of the more intriguing ones is TOC. For various reasons it has been different from many of the other developments proposed in the field, and controversial. In this paper we have attempted to use TOC as a case study of the lessons about new developments in the field and how a similar development might be handled in the future from an academic perspective.
After examining the different sides of the debate, it is our view that many aspects of TOC are not really new. The principles espoused by TOC have existed before the publication of *The Goal* and subsequent books on TOC. Most notably, mathematical programming methods, such as LP, traditionally used the binding constraints to seek the optimum (e.g., see Bock 1962, whose approach to teaching LP involved the “exchange rate in the bottlenecked resource”), and thus the ideas were well understood by the professional Management Science community. Furthermore, the whole structure of TOC has been explicitly taught as part of PERT/CPM much earlier than the debut of TOC. Thus the principles of TOC appear not to be an ‘invention’ as some proponents have stated. Rather it appears to be a refocus on some important aspects (simplifying and communicating) of process management in an easy to understand manner.

This of course has led TOC to be controversial. While both academia and practice have seen benefits from this refocusing on constraints, there has been criticism about its gospel type approach. Given this we fell that it is important to debate the developments in TOC to provide a fair and balanced view. Further, by doing so both the developers of new theories and who later do research and teaching related to the new development should be able to benefit from its lessons.

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