A Study of Using Critical Chain Project Management Method for Multi-Project Management Improvement

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Despite hundreds of reported accounts of successful Theory of Constraints (TOC) Critical Chain Project Management (CCPM) implementations, persons involved in a multi-project management still raise two immediate concerns: (1) TOC CCPM solutions are conceptual only and lack solid implementation steps to effect the change; (2) A good management foundation is a pre-requisite for CCPM implementation; building such a management foundation should be the priority. For the first concern, Goldratt developed Strategy and Tactics (S&T) trees to provide step-by-step guidance for effecting the change. However, other researchers have not extensively researched Goldratt’s approach and its effectiveness has not been empirically validated. Regarding the second concern, unless a successful case can disprove it, the concern will remain. Consequently, companies with a poor management foundation will hesitate to adopt CCPM and miss significant improvement potentials. This study presents a case study of a Chinese electronic components manufacturer that, like most other Chinese manufacturers, lacked a good management foundation. Nevertheless, the company adopted Goldratt’s CCPM S&T tree and the related logic and implementation steps were followed accordingly. The objectives of this case study are to validate that: (1) the logic of the CCPM S&T tree is robust and effective and (2) a good management foundation is not a pre-requisite for implementing TOC CCPM. The key to achieving successful improvements is to adopt the right concepts,
establishing mechanisms to stabilize the system first before kaizen (which is the focus of Lean and 6 Sigma) or assigning more resources.

Critical Chain Project Management (CCPM); Strategy and Tactics (S&T) tree

1. Introduction

Despite hundreds of reported accounts of successful Theory of Constraints (TOC) Critical Chain Project Management (CCPM) implementations (Realization Technologies, Inc., 2009) persons involved in a multi-project management immediately raised two concerns when we presented TOC CCPM (Newbold, 1998; Goldratt, 1997a; Goldratt, 2003; Goldratt, 2008) to them. (1) TOC CCPM solutions are conceptual only; even success stories lack in depth discussions on how to translate the concept into practice to reach results (how to implement CPM). Their major concern was the lack of solid implementation steps to effect change; (2) A good management foundation using a combination of Program Evaluation and Review Technique/Critical Path Method (PERT/CPM), Product Data Management (PDM) or Knowledge Management (KM) or Lean or 6 Sigma is pre-requisite, and reducing variation is the key. Building or improving the foundation (using management programs such as PERT/CPM, PDM, KM, Lean and 6 Sigma) should be the priority. Regarding the first concern, Goldratt acknowledged that TOC CCPM has previously not had solid implementation steps. Consequently, he developed Strategy and Tactics (S&T) trees (Goldratt, 2008) to provide step by step guidance for effecting change. Although the S&T tree logic developed by Goldratt is quite robust, TOC practitioners and academics have neither researched it extensively nor validated its effectiveness empirically.

With respect to the second concern, Goldratt (2009) noted that most variations that occur are local (at a task level). The most significant global variation that occurs in project is variation in on time delivery (OTD) i.e. the ability of the project management system as a whole to deliver the required quantity of the projects on time. Reducing local variations by using management programs such as PERT/CPM, PDM, KM, Lean and Six Sigma, etc, does not automatically guarantee improvement in OTD. He also claimed that in a chaotic system, reducing local variations, adding more resources or giving more lead time do not contribute to improvement in OTD and should not be the first priority; instead, the first priority should be to stabilize the system. TOC CCPM and buffer management (BM) provide mechanisms to stabilize a system and reduce variations in OTD, the only significant global variation in project management. Chang (2009) conducted an experiment to examine why it was so difficult to achieve high OTD in multi-project management environment. Thirty teams participated in the experiment involving 210 practitioners; the results indicate that the mode of project planning and execution (unrealistic project planning, a lack of clear working priorities and bad-multi-tasking) is the true root cause of poor OTD, not uncertainty (net task time variation). The results support Goldratt’s above claim. Kapoor (2009) and Jacob et al., (2010) also pointed out that the real reason for failures in implementing Lean or Six Sigma in project management improvement is that the implementation has been carried out inappropriately in two ways: reducing variability locally before stabilizing the system globally and continuing to use local efficiency measurements (milestone for each task). Following stabilization, a company can initiate a local improvement
program (such as Lean or Six Sigma), regulated by TOC BM analysis, to focus on the right places to reduce variation. Pirasteh and Farah (2006) conducted an empirical study of improvement using Lean and Six Sigma comparing cases that adopted TOC five focusing steps (Goldratt, 1997b) approach to focus their improvement efforts and those that did not adopt the TOC steps. The 5 focusing steps are: (1) identify the system’s constraint, (2) decide how to exploit the system’s constraint, (3) subordinate everything else to the above decision, (4) elevate the system’s constraint, and (5) if in the previous steps a constraint has been broken, go back to step 1. The results showed that improvements in companies that adopted TOC were 15 times better than those that did not adopt TOC.

However, successful TOC stories published in the past dealt with companies that always had a good management foundation. Often, these companies had even implemented PERT/CPM, PDM, KM, Lean and/or 6 Sigma before adopting the TOC CCPM solutions (Realization Technologies, Inc., 2009). As a result, the second concern remains unaddressed. This concern is particularly relevant to those companies in China, which typically lack a good management foundation and high level of local variations such as scope creep, delivery delay from suppliers, technology issues, resources and available time for projects are often inadequate, etc. Reducing variability is the focus of their improvement efforts and PDM, KM, Lean and 6 Sigma, etc. are the popular improvement tools. Observation reveals that variation in OTD (global variation in project management) among Chinese companies remains a major issue.

Therefore, this study presents a case study of a Chinese electronic components manufacturing company that, like most other Chinese companies, lacked a good management foundation. The company has high levels of variations in scope, suppliers, resources available, technology, etc. It has poor operational performance such as low OTD and long project lead time. This company applied TOC to improve its performance and adopted the CCPM S&T tree developed by Goldratt (Barnard, 2008) following the related logic and implementation steps. The objectives of this case study are to validate that: (1) the logic of the CCPM S&T tree is robust and effective and (2) a good management foundation is not a pre-requisite for implementing TOC CCPM. The key to achieving successful improvements is to adopt the right concepts, establishing mechanisms to stabilize the system first before kaizen (changing the processes to reduce variability and resources waste etc., which is the focus of Lean and 6 Sigma) or assigning more resources.

2. TOC CCPM Strategy and Tactics tree
2.1 Structure of Strategy and Tactics Tree

The TOC Strategy & Tactics tree (S&T tree) developed by Goldratt (Barnard, 2008) is the TOC Thinking Process application for facilitating whole-company ongoing improvement. Goldratt defines strategy as simply the answer to the question “what for?” or “what is the purpose (the desired effect) of?”. Tactics are the answer to the question “How do we achieve the strategy/desired effect (using a chosen mode of operation)?”. Based on these definitions, S&T entities always exist together; for different levels, S&T entities exist at each level. This means talking about S&T tree is actually talking about a structure that looks something like that shown in Figure 1 (Barnard, 2008). At the top are the strategy and tactics of the highest level. This study will call it the mission statement. Further down the tree addresses how to achieve the mission set out in the mission statement and goes into the functions with greater and greater
detail. However, a S&T Tree is only as valid as the assumptions on which it based. Each entity must provide the answers to “necessary assumption”, “what for”, “parallel assumptions”, “how” and “sufficiency assumption”. The S&T tree is, probably, the most powerful thinking process tool and the logical structure that enables focusing. The S&T trees bring clarity to implementations by enhancing management level communications and synchronizing various departments. The trees considerably shorten the time to reach results and smooth the transition from one implementation stage to the next. They also enable introducing the detailed implementation plan of TOC solutions into the public domain.

2.2 CCPM Strategy and Tactics tree

Figure 2 illustrates the CCPM S&T tree developed by Goldratt (2008). The highest level of the tree shown is the step, “Meeting project promises”. Six steps in a group at level two form the necessary steps sufficient to achieve the step level one, including “Reducing bad multi-tasking and WIP”, “Full kitting”, “Critical chain planning and buffing”, “Managing execution”, “Migrating client’s disruption” and “Managing sub-contractors or subcontracted sub-projects”. Going down to level three, there are four steps in a group, “Freezing”, “Accelerate project completion”, “Defrost mechanism” and “Releasing of new projects”, that form the necessary steps to achieve the step “Reducing bad multi-tasking and WIP”. The three steps, “Preparations according to priorities”, “Defining preparations” and “Worried clients” are necessary for the group to achieve the step “Full Kitting”. The other three steps, “Building good project plans/PERTs”, “Building critical chain plans” and “Staggering project portfolio,” are necessary for the group to achieve the step “Critical chain planning and buffing”. Finally, the four steps, “Task completion reporting”, “Task managers’ role in managing execution”, “Project managers’ role in managing execution” and “Top management role in managing execution” are necessary for the group to achieve the step “Managing execution.”

Figure 3a illustrates the strategic and tactic entities of level 1 and level 2. The strategy entity (what for) of level one is “The Company has very high due-date performance without compromising on the content or on the budget”, and its corresponding tactic entity (how) is “The Company implements Critical Chain Project Management (CCPM) culture and procedures”. To attain the level one objective, “The Company has very high due-date performance without compromising on the content or on the budget”, five necessary strategy entities of level two are necessary, including “Flow is the number one consideration (the target is not how many projects the Company succeeds to start working on, rather it is how many projects are completed)”, “A project is rarely launched before its preparations are complete”, etc. Each “Strategy entity” of level two must have a corresponding “Tactic entity” which details the tactic entity “The Company implements Critical Chain Project Management (CCPM) culture and procedures” of level one. This includes, “The company properly controls the number of projects that are open at any given point in time”, “The company uses the window of reduced load on resources that do the preparations to ensure that “full kit” practice will become the norm”, etc.

Click the button (shown on the bottom in Figure 3a) of steps 2.1, 2.2, 2.3 and 2.4 will go down their lower level. Figure 3b illustrates the strategy and tactic entities necessary for step 2.1. In order to attain the objective set out in step 2.1, “Reducing bad multi-tasking and WIP”, it requires four necessary strategy and tactics entities including 3.11.1 “Freezing”, 3.11.2 “Accelerate project completion”, 3.11.3 “Defrost mechanism” and 3.11.4 “Releasing of new
projects”. Each "Strategy entity" must have a corresponding “Tactic entity” which details the tactic entity of its higher level. Successful implementation of these four steps will lead to successful implementation of step 2.1 Similarly, Figures 3c-3e show the strategy and tactics necessary to achieve the objectives set out in steps 2.2 “Full kitting”, 2.3 “Critical chain planning and buffing” and 2.4 “Managing execution”. In addition to strategic and tactic entities, other components can be added to each step, and all can be considered as explanations: necessary assumption (explains why the given sep is necessary (as part of the group) to achieve the higher step), parallel assumption (explains why the step’s tactic will achieve the step’s strategy) and sufficient assumption (explains why all the steps of the corresponding lower level are sufficient to attain this step). Figure 4 illustrates all the information necessary to form the “Reducing bad multi-tasking and WIP” step. Detailed information of each step of the CCPM S&T tree can be found in (Barnard, 2008).

3. Overview of the case company

The case company focuses on developing, manufacturing, and marketing electronic components widely used in 4C products. Its total revenue for 2010 was about 200 million US dollars. The company’s product life cycle is about 6~12 months. Breakthrough technology emerges every 12 months. As a result, the company’s new product development division faces the following challenges:

1. Difficulty maintains a leading position since new technology develops quickly in this industry.
2. Difficulty controlling project schedules and poor on time delivery performance (30% on time delivery).
3. Difficulty evaluating the manpower and productivity of the new products development division.

The company’s current reality before implementing the TOC CCPM included the following problems:

1. A lack of unified planning methods. As a result, projects were released as soon as possible, causing serious bad multi-tasking.
2. When estimating the time required for tasks, they put safety time in every task and at every milestone or checkpoint.
3. Most projects were planned and executed by one engineer, forcing engineers to function more like coordinators than project managers. No support was provided from other resources, and the division did not operate as a project team.
4. Engineers received different orders from every level of management, and different managers asked for different reports from their respective milestones.
5. The company’s priority mechanism was based on “First in first out” as judged by engineers. However, the engineers had no control over supporting resources, and had to rely on managers to be their mediators. As a result, there was no way to reveal real project urgency.

These factors resulted in poor time to market performance, a long lead time for each project, and high expediting costs. The problems faced by the case company are common to many other electronic components companies in China.

4. TOC CCPM S&T tree implementation
The company first knowing the TOC is their top management attended the Viable Vision event conducted by Goldratt Group in August 2009 in China. After further evaluation of TOC CCPM, they chose to implement TOC CCPM, deciding that improving on time delivery for each new product development project should be the first priority. They contracted with an outside TOC CCPM expert (TOCE) certified by the TOCICO (TOC International Certification Organization). The implementation covered the following three phases:

**Phase one: TOC knowledge transfer**

The objective of this knowledge transfer phase was for the management team to gain sufficient knowledge and understanding of the relevant TOC generic concepts and CCPM solutions applicable to the company’s environment. A company-wide training commenced in May 2010 for the transfer of the TOC body of knowledge. The entire management team, from the board of directors to project managers, resources managers, task managers and engineers participated in the training. Experience has shown that people may learn but not understand; they may understand but not know how to apply the theory. Hence, examples, practices, role playing, quizzes and tests were crucial in this knowledge transfer phase. Games (Chang, 2009), computer simulation (Goldratt, 1997c) and TOC Insight project management (Goldratt, 2003) were also used as learning tools.

**Phase two: consensus and commitment**

The objective of this phase was to use the CCPM S&T tree set out in Figure 2 (Goldratt, 2008) to facilitate the management team reaching a consensus on the adoption of CCPM as their improvement tool and to obtain their commitment for its implementation. The TOCE first led the management team to read the CCPM S&T tree. The TOCE followed four steps in communicating the S&T tree:

*Step 1:* Start reading the highest level objective – the Strategy or “what for?”.

*Step 2:* Say something like “Since any logical tree is only as valid as its assumptions, we need to validate each of the assumptions to check if they can be considered Fact of life”. Then we will read the Parallel Assumptions (PA) and the “Tactics” or “How to” as a “logical conclusion” of these assumptions or “Facts of life”.

*Step 3:* Then read the Sufficiency Assumption (SA) as a “warning or reminder” and continue with the Necessary Assumption (NA), Strategy, Parallel Assumption and Tactics of the first lower level S&T entity (most left). Then read the second, third, etc. S&T blocks in the sequence defined from left to right.

*Step 4:* Continue in this way until the whole tree is completed (reading from left to right), checking with the “audience” regarding whether each assumption can be considered “a fact of life” and whether each Strategy & Tactic is a logical conclusion of these assumptions. According to the communication steps, we follow the CCPM S&T tree (Figure 2) and convert goals and plans into actionable instructions. The entity 1 is the highest level goal and the next down level entities 2.1 to 2.6 are necessary steps to accomplish the higher level step, also to accomplish step 2.1 we need to execute the next lower level entities 3.11 to 3.11.4. The sequence to execute the CCPM S&T tree starts from entity 1, then 2.1, then 3.11.1, 3.11.2, 3.11.3, 3.11.4, then back to 2.2, then down to 3.12.1, 3.12.2, 3.12.3, etc. During the review of the CCPM S&T tree, the TOCE asked management to raise reservations. Reservations are either negative branches (side effects) or obstacles that prevent achievement of some of the S&T tree entities. In preparation for the review, the participants were taught how to verbalize their
reservations correctly prior to the review process. The management team then split into smaller working groups. Each group worked on verbalizing the reservations raised by its members. The TOCE worked with each group to come up with the appropriate verbalized reservations, which were then presented to the whole management team. The management team then effectively dealt with the reservations with the help of the TOCE.

Broadly speaking, there are three types of reservations: a lack of knowledge; misunderstanding of or disagreement with an S&T entity; or a lack of commitment. Through the review of the S&T tree process described above, sufficient knowledge should have been conveyed to the participants and any misunderstanding of, or disagreement with, an S&T entity dealt with. An in depth understanding of the S&T tree and having addressed the potential obstacles and negative side effects eliminates reservations for its adoption and helps instill commitment for its implementation. Strong support by top management further helps secure commitment at lower levels. The S&T tree sets out the minimum mandatory changes required in a system to ensure the company is solidly on a process of ongoing improvement. The S&T tree provides a clear road map of all the changes that can be easily understood. The S&T tree also fully explains the logic for making the changes. Fully explaining the logic makes the S&T tree an effective communication tool across hierarchy, across functions and over time. This helps achieve consensus and secure support and commitment. The TOCE made sure the assumptions were reviewed by the participants and were accepted by them as fact of life. Management agreed that the resulting strategy/tactics were appropriate.

**Phase three: Implementation**

Having reached consensus and obtained commitment on the CCPM S&T tree, the TOCE explained the implementation sequence. An implementation team was formed and implementation projects were launched in July 2010. The intensive coaching and mentoring by the TOCE ended in October 2010 with limited follow-up training until December 2010. The company started the implementation process by training the project and task managers. Entity 2.1, “Reducing bad multi-tasking and WIP” was then immediately executed, and the actions taken as below:

**Freezing:** At the end of May 2010, there were more than 50 projects in the pipeline caused bad multi-tasking behavior. Prolific bad multi-tasking drastically increases the lead time of tasks and of projects, which leads to further missed commitments. The top manager in-charge of all projects was asked to determine the prioritization of projects and instruct to freeze (cease activities on) enough of the lowest priority projects. The currently released projects were then sorted by the determined priorities and 25% of the whole projects were decided to be frozen. The proper actions were taken to ensure full adherence to the freezing decision.

**Accelerate project completion and Defrost mechanism:** The optimal number of the various types of resources needed for each open project was determined and the freed resources from the frozen projects were used to prudently strengthen the open projects. Proper manning decisions were also done for the frozen and to be released new projects. When a project completed a frozen project is defrosted. The sequence of defrosting projects is according to the agreed projects prioritization determined in the “Freezing” step.

**Releasing of new projects:** When the time arrives to release new projects, steps 2.12 “Full Kitting” and 2.13 “Critical chain planning and buffering” should be in place. At that stage, a system to release new projects using the CCPM concepts is ready. As soon as the 25% of open
projects were frozen, the case company began implementing entity 2.2 “Full kitting” as below:

**Preparations according to priorities:** A Full-Kit manager was appointed. The relevant resources were instructed to complete the preparation steps first for the running - not frozen – projects, then to complete the preparations for frozen projects. Only when (most of) the above was done they were guided to work on the preparations for the new projects waiting to be released. They always follow the projects priority.

**Defining preparations:** The Full-Kit manager officially defined those activities which should be titled preparations. The company then took the actions to ensure that resources (those conducting the preparations and project managers of frozen and unreleased projects) are guided and monitored to work only on the preparation activities as defined. Any project did not allow to be released into the system if the project does not have all its pieces in place. Same rule for tasks within the system, and this is managed by the task managers. Entities 2.1 and 2.2 took about two months and the case company moved on to implementing entity 2.3 “Critical chain planning and buffering”.

**Building good project plans/PERTs:** Several project network building workshops were conducted to create project network templates. All relevant projects (projects which are not to be soon completed and the projects to be released in the near horizon) were considered in order to determine the generic projects. The implementation team constructed the templates per each generic project making sure that the resulting PERT will be properly detailed. Optimal number of resources per task and per project was determined. Per each relevant project its project manager worked with the key people that constructed the template to properly modify the template to fit the specific project. Four templates were developed. The objectives, deliverables and successful criteria of each template were discussed and defined clearly; common goals were shared by the developed team.

**Building critical chain plans:** An advanced CCPM workshop was conducted for implementation team. For each relevant project the project-planning team continued by following the Critical-Chain process to turn the initial PERT into a Critical-Chain-PERT. The templates were finalized.

**Staggering projects portfolio:** The project-planning-team chose the final test as the drum (heavy loaded resources) to work as a staggering mechanism to plan project start date and completion date. Actions were taken to ensure that projects are released according to the plan (legs having different lead-times are released at correspondingly different dates). Actions are taken to ensure that due dates for new projects are committed only according to the staggering mechanism (or top management’s decision to postpone a specific existing project). Entity 2.3 “Critical chain planning and buffering” took about two months too. After entity 2.3 completed, entity 2.4 “Managing execution” was launched as below:

**Task completion reporting:** A workshop explaining the task completion reporting system was given to all task managers: what is required from them to report on a daily basis, how this information is going to be used and that they will, at last, be able to obey only the formal priority list. The company then launched the daily reporting (by task managers - not by the resources) procedure and relentlessly enforces it.

**Task managers’ role in managing execution:** Every day the task manager gets two lists of tasks: The list of tasks currently being executed and the list of tasks that are incoming, both sorted according to their up-to-date priorities. Following the priorities, task managers assign the
optimal number of resources to tasks. Based on the tasks’ priority of currently executed tasks the task managers, aimed at minimizing/eliminating delays, decide on the level and type of intervention. For each incoming task, the task manager ensures the necessary conditions to start the task are in place: approvals, designs, (uninterrupted) resources etc.

**Project managers’ role in managing execution:** Project managers review daily the list of tasks penetrating the most into the project buffer and check if recovery actions are taken or required to ensure that the project is effectively progressing. In extreme cases the project’s Critical Chain PERT (and even the template) will be updated.

**Buffer meetings:** The buffer meeting provided feedbacks and information to assist in decision making. These meetings reviewed project progress, ensured the correct implementation of all steps, and used feedback provided by the buffer status for remedial actions. The case company held daily buffer management meetings to expedite the task or project that were red.

**Top management role in managing execution:** Top management reviews periodically (every two weeks) the projects’ status. For projects whose progress is not satisfactory, the recovery actions are examined. A commercial CCPM software system (planning and execution of multi-project) was introduced before starting the step 2.3 to manage the project planning and execution. Several workshops were conducted to train relevant people to use the system. Detailed procedures to implement step 2.5 “Migrating clients’ disruption” and step 2.6 “Managing sub-contractors or sub-contracted sub-project” were also developed. The time to implement all these entities totaled about eight months and the results are significant (see Section 5).

The case company managed the implementation as follows: (1) Monitor the work of all the projects; (2) Daily buffer meetings with implementation teams to monitor progress and ensure they were on track; (3) Weekly meetings with top management to keep them updated and secure their continued commitment; (4) Management team being involved in all the major decisions in the implementation process; (5) Escalating issues to top management whenever the issues might risk the successful completion of implementation.

5. Results

After four months of implementing “Reducing bad multi-tasking and WIP” and “Full kitting”, unfrozen projects flew smoothly, several potential delay projects were identified, recovered and completed on time. Partial of the resources from the frozen projects were used to prudently strengthen the open projects and partial of them were instructed to complete the preparation steps first for the running - not frozen – projects, then to complete the preparations for frozen projects. More projects completed on time and early. The rapid and significant improvements created the momentum (confidence and interest) for the case company management team to charge on with other improvement initiatives. They then implemented “Critical chain planning and buffering” and “Managing execution”. Over the eight months period, the following results were achieved:

1. Project due date performance increased from <30% to >85%.
2. Increased advantage of time to market, in addition to technology.
3. Reduced project lead time by approximately 30~50%.
4. On-time risk management and effective decision-making.
5. Better controls of resource loading and improved R&D schedule and cost evaluation.
6. Improved planning and executing abilities with a holistic view, forming an effective management model for the new products development division.

These results demonstrate that significant improvements can be achieved swiftly by following TOC strategies and tactics despite the lack of a strong project management foundation, all without increasing manpower or equipment. Other positive side effects followed. At the start of implementation, far too many projects had been released. The system was overloaded and engineers were so many tasks on hand (the highest is 20 tasks—very bad multi-tasking behavior). Freezing of projects enabled the engineers to complete and clear out pre-existing tasks. Engineers saw tasks complete fast and more to an extent they had never seen before and were enthusiastic to continue with the ensuing improvement initiatives.

At the start of implementation, there were a large number of overdue projects and the engineers were overloaded. No system was in place to prioritize different tasks and frequent switching of task priorities in response to project managers (or top management) complaints aggravated the problem. Many urgent tasks made engineers tense. With the introduction of CCPM, tasks were released and processed in the order of delivery dates and the priority of different tasks was clearly understood by all the involved people from the senior management to the engineers. Switching task priorities only occurred after receiving a new urgent task. Less shouting and expediting took place among project managers, significantly reducing tension. Highlighting the status of urgent tasks using red or yellow colors further aided visible task priorities. The case company was able to achieve >80% on time delivery within eight months of implementation. Previously, case company management had to keep expediting overdue projects and decide, on an arbitrary basis, the priorities of overdue tasks. Engineer’s tension was visible and management had to spend time reducing frictions on them. With a clearly understood system that set tasks priorities in line with their urgency, the number of overdue projects reduced, and management no longer needed to deal with expediting overdue tasks and was able to focus time and effort on long term planning.

6. Lessons learned

Although CCPM was the right solution for case company, without the following key success factors, the case company could not have achieved the results in the short period of about eight months.

6.1 Top management support and commitment

For the case company, implementing CCPM involved multi-paradigm shifts and company-wide changes. Securing strong support and commitment from top management was imperative as the company made one change after another. The commitment of top management was not just lip service, but was real as follows: (1) Management committed a whole month of time and fully participated in the TOC knowledge transfer and CCPM S&T verification process. The implementation of the program involved changes in working habits and culture. Even with the robust logic of the S&T tree, there can be occasional hesitations and reversions to old practices. In these situations, without a thorough understanding of the TOC knowledge and CCPM S&T tree, it would be impossible for top management to support the program and require subordinates to make the necessary changes. (2) Management also committed to staying
focused on implementing the CCPM S&T tree. This means the general manager and his top management team decided to stop all other initiatives requiring management attention that were not part of the CCPM S&T tree. Given the multi-paradigm shifts and company-wide changes required, the author believes the single most important success factor is the support and commitment of top management.

6.2 Stick to the CCPM S&T Tree

The CCPM S&T tree provides robust and complete implementation steps and leads to desired results if properly followed. Previous TOC implementation experiences show that the various CCPM S&T tree must be implemented in a specific order. Although the CCPM S&T tree sets out the order of implementation, when reservations arise, the participants often use their personal experience to “modify” the solution to deal with their reservations. This leads to deviations from the CCPM S&T tree and improper implementation. An improper implementation inevitably delays achievement of the target results and weakens the commitment to implement the solution as a whole. An organization must strictly adhere to the order of implementation. Only proceed to the following step after confirming satisfactory completion of the previous step. A successful implementation generates certain signals. By observing these signals, buffer management meetings can tell whether the organization has correctly implemented an entity. For instance, upon successful implementation of “Reduced Bad Multi-tasking and WIP” and “Full Kitting”, number of open projects and project lead time should both decrease; the number of live tasks should start to clear up as the WIP level drops. If a company starts to implement “Managing execution” without having successfully implemented “Reduced Bad Multi-tasking and WIP” and “Full Kitting”, there will be so many red tasks (urgent tasks) that it will be impossible to implement “Managing execution”.

6.3 Must have quick and noticeable wins

The most important assumption in the CCPM S&T tree concerning implementation is this: to ensure an outstanding start of a major project, it is vital that each of the first substantial actions results in immediate substantial benefits. The CCPM S&T is designed to ensure that the implementation follows the logic of the tree a step at a time. The first step is designed to have no relevant obstacles to implementation. The successive steps are easy to implement after the first one has demonstrated substantial benefits. Hence, getting significant and noticeable wins quickly turns resistance to change into momentum for change and is a key success factor. In the case company, within two months of “Reduced Bad Multi-tasking and WIP” and “Full Kitting” implementation, both management and engineers could see the improvements and benefits. They were thus motivated to continue implementing the other changes.

6.4 Collaboration through sharing the buffer

It is a valuable lesson to learn that by showing the schedule without safety and by sharing the buffer, cooperation/teamwork is much enhanced. This can be attributed to the fact that by revealing the true picture, communication among project members and top management was accelerated. Most people have the impression that communication is greatly enhanced thanks to buffer management. They regard CCPM as a communication vehicle. In this case, it seems the simple and easy buffer mechanism enhances communication and creates teamwork.
throughout project environment.

6.5 Sustainability is the key
Sustainability is the key to achieving significant improvement. Sharing the benefits of improvement with employees through bonuses and pay raises provides momentum for sustainability. Holding a daily buffer meeting is an important method for sustaining improvements. During buffer meetings, all participants can see the process of change, the obstacles, the negative side effects and the benefits of the improvements. The participants also share with each other what they have learned during implementation that reinforces the upward spiral. At case company, the implementation phase took place within three months after the participants first learned about TOC. Inevitably, participants' understanding of the TOC body of knowledge was limited. To sustain improvement efforts under these circumstances, it is important that follow-on training by TOC experts be conducted during the first year of implementation to reinforce TOC knowledge and ensure that participants do not revert to previous work practices.

7. Conclusions
This study presents a case study of a Chinese electronic components manufacturing company, like most other companies, lacked a good management foundation. It had high levels of local variations and poor operational performance poor operational performance such as low OTD and a long project lead time. By following the CCPM S&T tree developed by Goldratt, within eight months the company achieved significant improved results. Project lead time was significantly reduced and OTD reached over 85 percent. This successful case provides evidence that: (1) the logic of the CCPM S&T tree is robust and effective, and (2) the key to achieving high OTD in a multi-project environment is to establish mechanisms to stabilize the system first before adopting continuous improvement programs to reduce variability (which is the focus of Lean and 6 Sigma) or assigning more resources.

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