Application of CCPM to Construction Project

건설프로젝트에 CCPM의 적용

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Abstract

The Theory of Constraints (TOC) is an approach and a philosophy that is used to develop specific management techniques. It was first popularized by the novel, The Goal, that applied the principles to operations management. Since 1997 it has found application in two areas within project management. The first application is scheduling of a single project to reduce project duration and simplify project control. there is a further application to allocate resources that are shared by concurrent project. It is the objective of this paper to explore the fundamentals of critical chain and to pursue an application of critical chain method to construction project by a case study.

Keywords : TOC, CCPM, Project management

1. Introduction

The engineering and construction industry faces formidable challenges. As a whole, the industry worldwide continues to perform unsatisfactorily. It suffers from low profit margin, persistent project overruns in schedule and budget, and is plagued with claims and counter-claims.[1)]

The construction industry receives many criticisms. Mohamed[2)] claims that the current practices and mechanism of the construction are inherently inefficient, which inevitably leads to wastes. De la Garza[3)] thinks that the construction industry productivity has been static for almost two decades.

The Theory of Constraints (TOC) is an approach and a philosophy that is used to develop specific management techniques.[4)] It was first popularized by the novel, The Goal[5)], that applied the principles to operations management. Since 1997 it has found application in two areas within project management. The first application is scheduling of a single project to reduce project duration and simplify project control. This is the main theme of the novel Critical Chain6). Only towards the end of this novel there if some indication of a further application to allocate resources that are shared by concurrent project.

It is the objective of this paper to explore the fundamentals of critical chain and to pursue a application of critical chain method to construction project through a case study. The paper is organized as follows. Section 2 offers a short overview of the fundamentals of critical chain method. Section 3 discuss about domestic construction project case applying critical chain method. Section 4 provides overall conclusions and offers some suggestions for future research.

2. Critical chain method

Goldratt proposes a Critical Chain Project Management (CCPM) method, to overcome some of the problems inherent in the traditional project planning and scheduling methods, notably the basic Critical Path Method (CPM). The critical chain method, applying the Theory of Constraints (TOC), offers an enhanced approach to manage the associated risk and uncertainty in the project value chain and to achieve improved performance in project time management.

2.1 Theory of Constraints

Theory of Constraints (TOC) is a common-sense way of understanding a system' s performance. TOC states that, "Any system must have a constraint that limits its output", The system' s constraint is like the weakest link of a chain. No matter what you do to improve other links in the chain, the chain does not become stronger until you improve the strength of the

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weakest link. Goldratt proposes a five process to achieve continuous improvement and to get the most out of a system, in relation to the stated system goal. Fig. 1 illustrates the sequence of the five steps.

The system’ s constraint is the part of the system that constrains the objective of the system. In Step 1 this needs to be identified. If it is a machine, for instance, then the maximum possible utilization needs to be achieved. This may mean running the machine during the lunch hour, with operators staggering the break, or reducing the number of changeovers. It will mean ensuring that there is always work for the machine to do. Thus the system’ s constraint is exploited (Step 2). If this is the constraint, then there is no point running other machines at a higher production rate: so every other planning decision needs to be subordinated to the schedule required to keep the bottleneck machine running (Step 3). To improve the objective the system’ s constraint may need to be elevated, it might be run during an additional shift, thus increasing its output. The constraint, the capacity of the machine, has been increased, or elevated (Step 4). The difference between Step 2 and Step 4 relates to the amount of investment required, whether in terms of time, effort, money, or willingness. The difference is sometimes pithily expressed as “whatever we can do tomorrow is Step 2”. The application of Step 4 may have changed the system’ s constraint. With its increased capacity, the original bottleneck may no longer be constraining the system, so the new bottleneck needs to be identified, and the process repeated (Step 5). Thus, this is a process of continual improvement. Though this example comes from the production environment, TOC is applicable to every system. Critical Chain seeks to explain how this approach can be applied to project management.

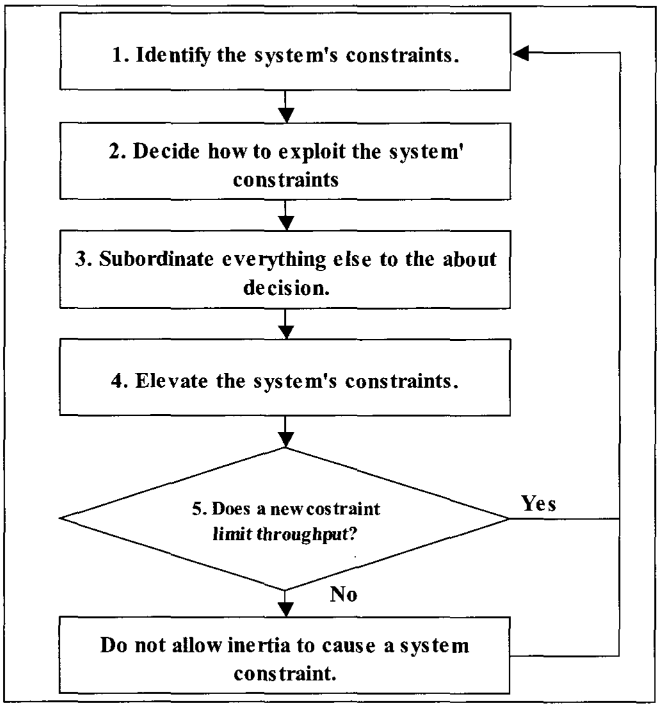

Fig. 1. Five steps in TOC approach[6)]

2.2 Uncertainties in project chain

Goldratt reckons that there are three kinds of uncertainties in project planning and scheduling namely, (1) activity time uncertainty, (2) path time uncertainty, and (3) resource uncertainties. Generally, when a project planner making a schedule, he would add a “safety” allowance or “padding” in his time estimation to provide localized protection to an activity.

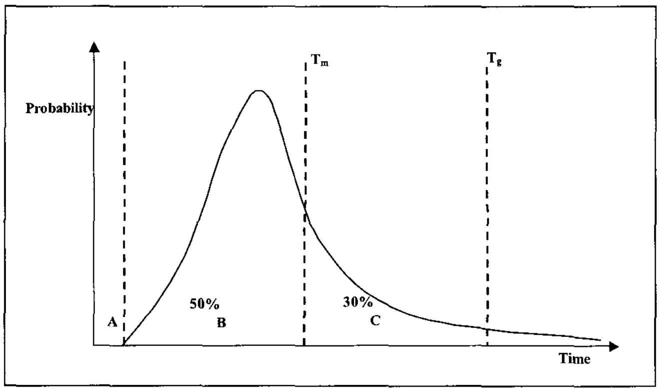

Fig. 2. Activity time uncertainty[1)]

For illustration as shown in Fig 2, each activity is assigned a segment of time Tg, the target time. the possibility of the activity executor to finish the activity by Tg is, for an example, 80%, which is 30% above the mean time, Tm. The problem is that, in practice, not all activities need Tg to finish. the activity executor may well finish the activity in less than Tg or even Tm. However, the executor will only submit his work at Tg, which was the estimated “due date”. therefore, Goldratt opposes the idea of paying too much attention to intermediate “due dates” as this encourages the wasting of time. The time wastage is due to a number of causes, which include:

1) Student’ s Syndrome: once a resource has negotiated a Tg, which contains “safety” margin which is viewed as a “padding”, the executor re-evaluates the task and decides how long it will most likely take, say Tm. Then he gets caught up working on other tasks, knowing he has built-in “safety”. when he realizes the remaining duration is squeezed to become just enough to meet the due date, he quickly ramps up the effort level. At that point, if he encounters an unexpected problem as Murphy’ s Law strikes, the deadline is missed. If he crashes the task, quality would likely be compromised.
2) Parkinson’ s law: work expands to fill the time available due to the “padding” due dates.

3) Multi-tasking: the effect of multitasking is that fragmentation of task and equipment' s set up time would cause task to delay due to loss of concentration. The impact is more serious when dealing with creative work.

4) Merging events: because task can have multiple necessary predecessors, delays are usually passed on, while gains are not. In a dynamic situation, subcritical project paths may turn into a critical path when they slip.

2.3 Critical chain approach

PERT deals with uncertainty in the same way for all activities, whether or not they are on the critical path. The approach of the critical chain method is to relocate the safety times in strategic positions. Time estimates may be reduced (if it is known they are inflated), but safety buffers of time at the end of the project, called the "project buffer" shown in Fig 3, are added. This will have the effect of reducing the length of the critical path. It should be noted that the decision to cut the overall safety time is subject to the level of confidence that concerned parties have in this process. the Goldratt Institute recommend that the first emphasis should be on finishing on time, before looking for a reduction in overall time: in the TOC language, they go for 'exploit' before 'elevate'.

The activities on the critical path need to be able to start when the previous activity on the path are completed. They should not be required to wait for any sub-critical activities. So "feeding buffers" are added at the end of the non-critical sub-paths shown in Fig 4. Resource buffer may be needed to deal with critical resources, in order to protect the critical chain for resource availability. It is argued that the drastic cut in activity times will have the benefit of removing procrastination, the "student syndrome", because those involved are concerned about whether or not they can finish the activity the on time.

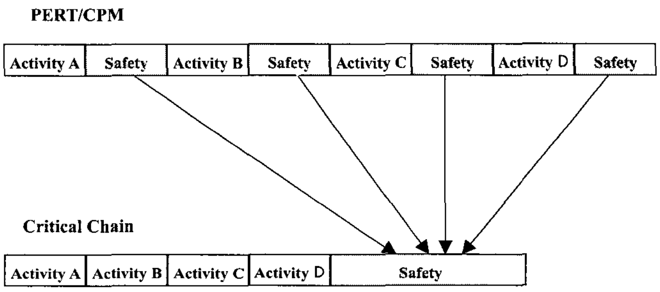

Fig. 3. Comparison between PERT/CPM and Critical Chain Method with regard to safety time[13]

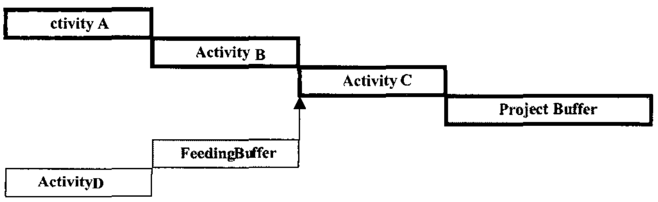

Fig. 4. Arrangements of buffers in the TOC approach to project management[13]

2.4 The process to create a single critical chain

The five focusing steps in Fig 1 represent the TOC approach to ongoing improvement and are applicable to the basic steps of the process to create a single critical chain project schedule.

The basic steps of the process are as follows:

1) Identify the critical chain

a. Lay out the late-finish network of tasks. The tasks must identify the time duration estimate and primary resource requirements. (For task with multiple resources, identify the primary resource you believe will be a constraint. If there are several constraint resources, break the task up for each primary resource.)

b. If you do not have resource contention in your project, go to step 1) f.

c. Identify the contention you will resolve first. That should be the contention nearest project completion or the one that shows the most conflict. If several contentions show about the same amount of potential conflict, choose the first one you come to working backward from the end of the schedule.

d. Remove resource contention by re-sequencing task earlier in time. (Do not worry about creating new conflicts with this step; you will resolve those in sequence.)

e. Return to the end of the schedule and follows step 1) d for the next resource. As you resolve conflicts for the next resource, you must maintain the lack of the conflict for the resources you resolved earlier. Repeat until all identified resource types are resolved.

f. Identify the critical chain as the longest chain of dependent events.

2) Exploit the critical chain

a. Review your plan to determine if there are obvious ways that re-sequencing can shorten the overall project duration. If so, do it. Do not spend a lot of time trial and error testing various solutions. You will usually get a good enough solution on your first or second try.

b. Add the project buffer to the end of the critical chain

c. Add resource buffers to the critical chain.

3) Subordinate the other tasks, paths, and resources to the critical chain

a. Protect the critical chain by adding CCFBs to all chains that feed the critical chain. Size the buffers using the longest preceding path.

b. Resolve any resource contentions created by adding feeding buffers through re-sequencing tasks earlier in time.

c. Move earlier in time any dependent task preceding those moved.

4) Elevate (shorten) the lead time of the project by using added resources for certain windows of time to break contention.

5) Go back to step 1, identify the critical chain. Do not allow inertia to become the constraint.

A critical chain path schedules (i.e., assigns dates) only to the start of the chains and the completion of the project. Avoid publishing and discussing individual task start and complete dates-they are meaningless. For the reason, you may want to consider talking about the critical chain plan, rather than the critical chain schedule.

2.5 Exploiting the multi-project constraint

The constraint resource becomes the drum for the company projects (like the drummer on the ancient galleons setting the pace for the rowers). therefore, the procedure to exploit this resouce is as follows:

1) Identify the company constraint resource.

the company constraint resource should be the resource that determines the greatest amount of critical chain duration on your projects. It usually will be apparent as the resource that is frequently in short supply and is often called on to use overtime. If several resources exhibit the same behavior, select one based on the unique contribution of your company. Otherwise, select the one usually demanded nearest the beginning of a project.

2) Exploit the company constraint resource.

a. Prepare the critical chain schedule for each project independently.

b. Determine the project priority for access to the constraint resource.

c. Create the constraint resource multi-project schedule: the drum schedule. Collect the constraint demands for each project and resolve contentions among the projects to maximize company throughput. In other words, complete most projects early.

3) Subordinate the individual project schedules.

a. Schedule each project to start based on the constraint resource schedule.

b. Designate the critical chain as the chain from the first use of the constraint resource to the end of the project.

c. Insert capacity constraint buffers (CCBs) between the individual project schedules, ahead of the scheduled use of the constraint resource. That protects the drum (constraint) schedule by ensuring the input is ready for it.

d. If insertion of the CCBs influences the constraint resource schedule, resolve contentions.

e. Insert drum buffers in each project to ensure that the constraint resource will not be starved for work. Place them immediately preceding the use of the constraint resource in the project.

4) Elevate the capacity of the constraint resource.

5) Go back to step 2 and do not let inertia become the constraint.

3. A case study

We intended to study the application of CCPM to construction project by a domestic case. This case is river levee work and is divided into three areas(Area A, B, C). The main works are a bank protection construction and a poor subsoil improve -ment construction. The summary of this case (area A) is presented in Table 1.

Table 1. Summary of a case project (Area A)

Activity	Duration	Start Date	Finish Date	Budget	Rate
river levee costruction	70	2003-01-01	2003-03-11	₩4, 410, 000, 000	100%
suface soil removal	18	2003-01-01	2003-01-18	₩89, 523, 000	2.03%
work road build	12	2003-01-06	2003-01-17	₩97, 127, 000	4.47%
structure demoition	18	2003-01-06	2003-01-23	₩32, 634, 000	0.74%
rubble pile	20	2003-01-11	2003-01-30	₩680, 904, 000	15.44%
poor subsoil improvement	18	2003-01-16	2003-02-02	₩, 064, 133, 000	24.13%
soil conveyance	20	2003-01-21	2003-02-09	₩975, 051, 000	22.11%
banking	20	2003-01-21	2003-02-09	₩417, 627, 000	9.47%
alignment arrangement	13	2003-01-31	2003-02-12	₩58, 653, 000	1.33%
revetment block	20	2003-02-10	2003-03-01	₩645, 183, 000	14.63%
joint plan	15	2003-02-20	2003-03-06	₩102, 753, 000	2.33%
appurtenant work	20	2003-02-20	2003-03-11	₩146, 412, 000	3.32%

3.1 Critical chain scheduling

Total Project was constructed the association of three areas with the same task. Resource capacity was constrained by a area' s capacity. For critical chain scheduling, we made five scheduling charts in order(Fig 5~Fig 9). Firstly, scheduling chart applying CPM was made, which wasn' t considered resource conflict problems. Secondly, scheduling chart was considered multitasking in order to solve resource conflict problems, but caused project duration to increase. Thirdly, scheduling chart was constructed three areas in sequence in order to solve resource conflict problems, but also caused project duration to increase . Fourthly, scheduling chart was performed resource leveling in order to solve resource conflict problems. Finally, scheduling chart was applied to critical chain method that safety buffer to each activity integrate as "project buffer" at project end.

we assumed that safety buffer defined 30% to each activity and analyzed sensitivity ranged from 10% to 50% on safety rate in Section 3.3.

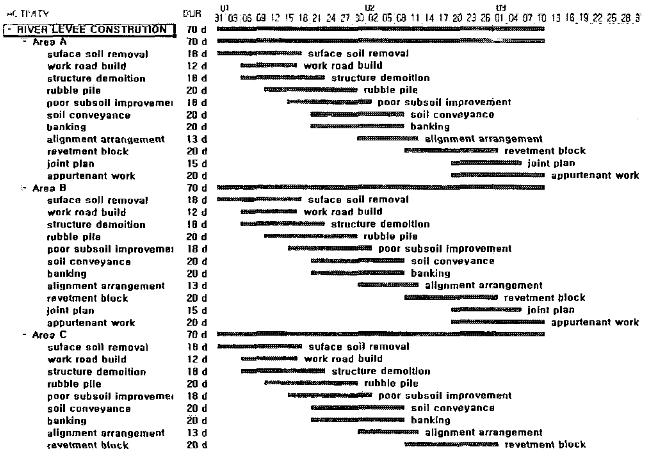

Fig. 5. Scheduling chart applying CPM

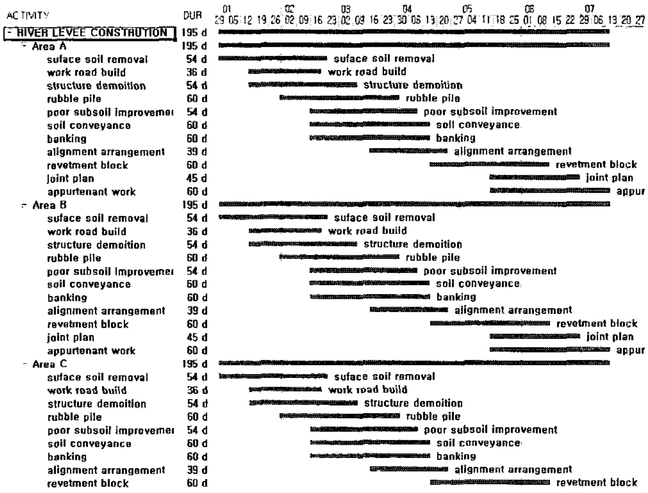

Fig. 6. Scheduling chart considering multitasking

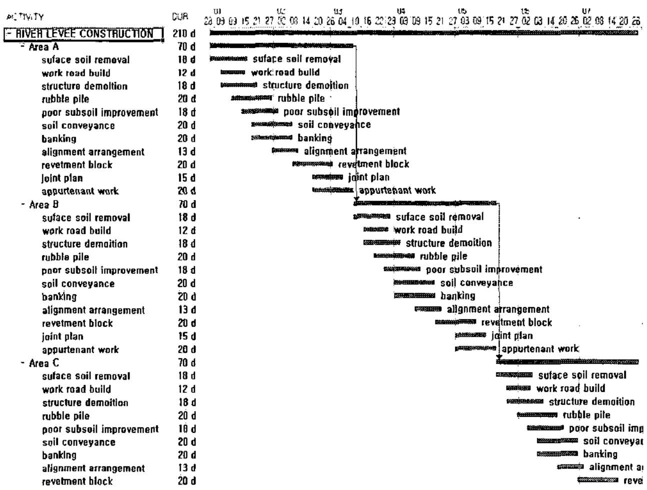

Fig. 7. Scheduling chart constructing three areas in sequence

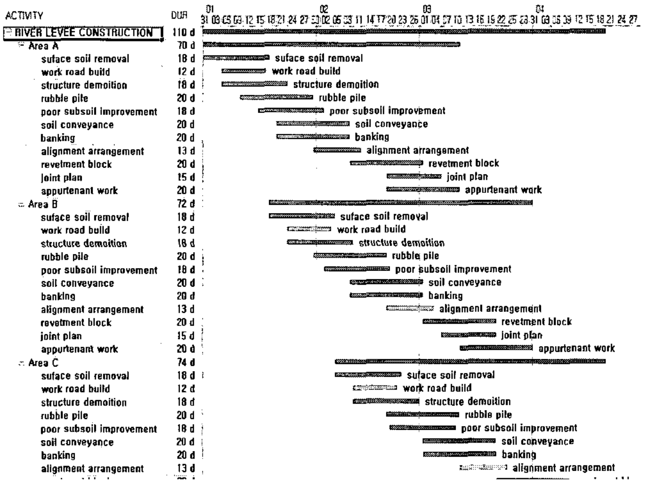

Fig. 8. Scheduling chart performing resource leveling

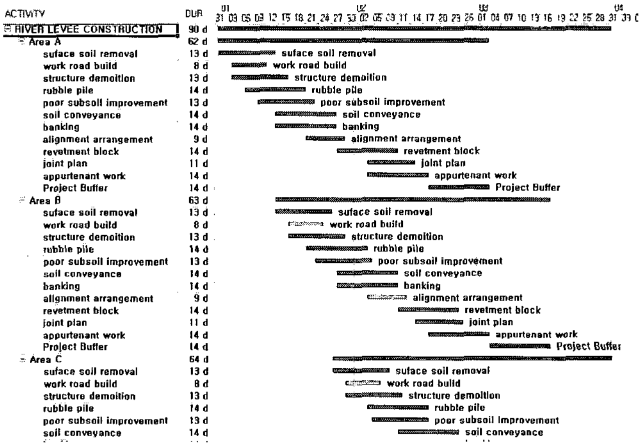

Fig. 9. Scheduling chart applying critical chain

3.2 Duration reduction and solving of resource conflict

Through making five scheduling chart, we intended to pursue a presented duration and resource subject. Fig. 10~11 was presented relationship between resource and duration about each scheduling chart. Scheduling chart applying CPM and Multitask respectively was shown resource conflict problem (300%) and resource under-allocation

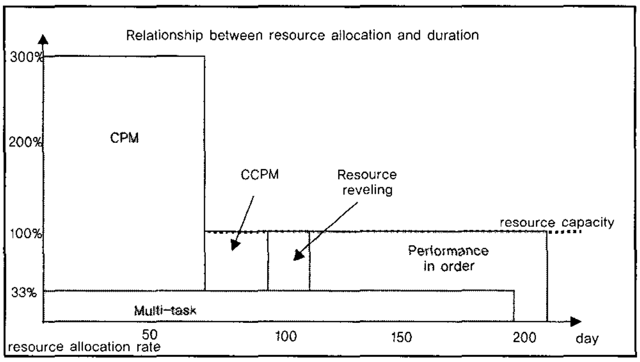

Fig. 10. Relationship between resource and duration

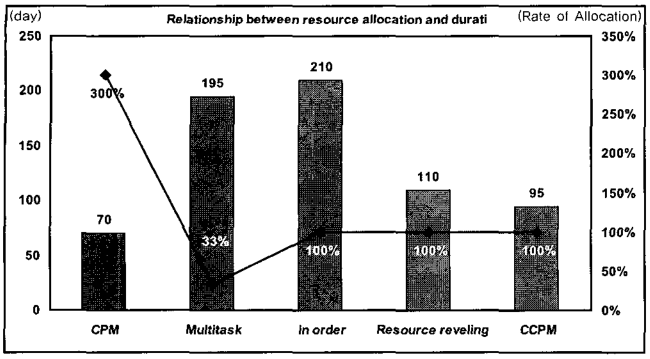

Fig. 11. Relationship between resource and duration

problem(33%). Remaining scheduling chart(Fig. 7, 8, 9) kept proper resource capacity level(100%) and especially scheduling chart applying critical chain was shown the largest project duration reduction(95 days) relat -ively among scheduling charts keeping proper resource capacity level(100%).

We compared critical chain scheduling with critical path scheduling on resource efficiency problem(Fig 12~Fig 13). Critical path scheduling is existed much unused times between resources. because of the unused times, unnecessarily much cost might be spent. For reducing unused times resource scheduling management is performed and critical chain scheduling considers resource conflict in advance in contrast to PERT/CPM

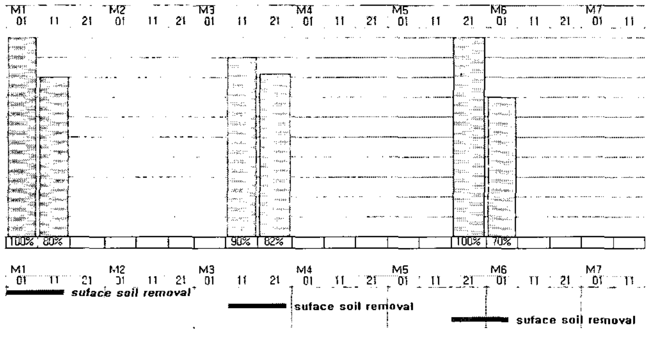

Fig. 12. Resource efficiency problem (CPM)

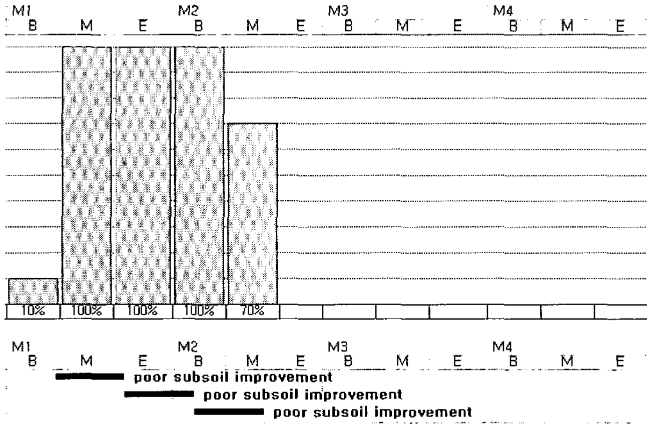

Fig. 13. Solving of resource efficiency problem (CCPM)

3.3 Sensitivity analysis

We performed sensitivity analysis about safety rate in each activity. Because safety rate can' t be defined closely, we analyzed it range from 10% to 50% on safety rate in each activity. Then through being variation of safety rate, we analyzed the variation of total project duration and cost saving. through the variation of safety rate in each activity, total project duration and cost saving respectively changed within ranging from 108 days to 77 days and from ₩1.4 billion to ₩6.6 billion. It is important subject to determine optimal safety rate all projects and requires continuous endeavor for it.

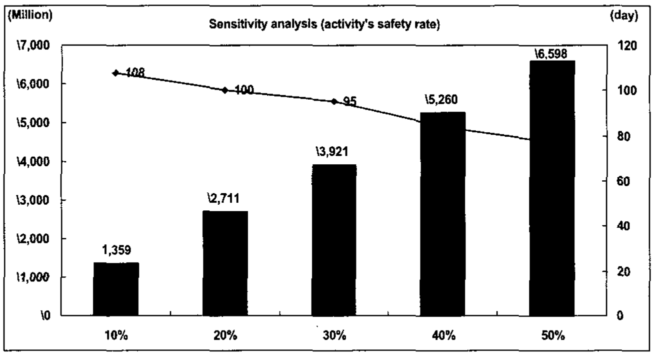

Fig. 14. Sensitivity analysis on safety rate in each activity

4. Conclusions

Results exploring the fundamentals of critical chain and studying a application of critical chain method to construction project with a domestic case study are as follows:

An application of critical chain was taken better improvement about inherent problems of CPM that are especially the uncertainty of duration estimate on individual activity and resource conflict problem.

In contrast to PERT/CPM, which may be characte -rized as dealing solely with certain technical aspects of project management, the application of the critical chain method focuses very much on how senior management deal with human behaviour, both in terms of construction the project network, and in managing it afterwards. As far as the technical aspects are concerned, if satisfying the milestones is not creates performance for your company but simply a tracking tool, inserting buffers at the appropriate points in the project network by identi -fying the critical chain is actually a better tool.

Further research can be directed in the areas listed later:

1) Application of TOC approach to other areas of project management.[1)4)]

2) The practical approach for scheduling multi-project sharing multi-resource.

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요 약

제약이론은 특정한 관리기술을 개발하는데 사용되는 접근방법이며, 철학이다. 운영관리상에 적용되었던 소설 "The Goal"에 의해서 처음으로 널리 보급되었다. 1997이후로 프로젝트관리의 두 가지 영역에서 적용되어 왔으며, 그 첫 번째 적용은 단일프로젝트에 대한 공기단축과 프로젝트 통제관리의 간소화를 위한 공정관리분야이며, 두 번째 적용은 동시에 수행되는 여러 프로젝트에 의해서 공유되는 자원의 효과적 관리이다. 이 논문은 프로젝트 관리에 적용된 제약이론인 애로사슬(Critical chain)의 원리에 대해서 연구하고, 국내의 건설프로젝트에 적용하는 것을 목적으로 한다.

Keywords : 제약이론, 애로사슬 프로젝트관리