APPROACHES IN PROJECT MANAGEMENT ACTIVITIES AND CRITICAL CHAIN PROJECT MANAGEMENT

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BY

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PLAGIARISM

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

In this thesis, approaches and different methods in the discipline of Project Management are examined. In addition, the CCPM (Critical Chain Project Management) method, which finds place in the literature and applied in different sectors around the world, and there are opinions that more positive results are obtained than the classical methods, has also been examined deeper. The data collection method of the research is the survey method. Within the scope of the study, the awareness and applications of the CCPM method in our country were tried to be investigated through a questionnaire. According to the survey results, the awareness and application level of CCPM is quite low in our country. With this survey, the importance of some potential benefits in the literature was also questioned and it was seen that the participants expected a project management method to be beneficial especially in terms of reducing costs and shortening project delivery time. It has been suggested that these potential benefits can be experienced if the awareness and applications of the CCPM method increase with future studies.

Key words: Critical Chain Project Management, CCPM, Project Management

ÖZET

Bu tezde, Proje Yönetimi disiplinindeki yaklaşımlar ve farklı yöntemler incelenmektedir. Ayrıca literatürde yer alan ve dünya çapında farklı sektörlerde uygulanan ve klasik yöntemlere göre daha olumlu sonuçlar alındığına dair görüşler bulunan CCPM (Kritik Zincir Proje Yönetimi) yöntemi de daha derin olarak incelenmiştir. Araştırmanın veri toplama yöntemi anket yöntemidir. Çalışma kapsamında bir anket aracılığıyla CCPM yönteminin ülkemizdeki bilinirliği ve uygulamaları araştırılmaya çalışılmıştır. Anket sonuçlarına göre ülkemizde CCPM'nin bilinirliği ve uygulama düzeyi oldukça düşüktür. Bu anket ile literatürdeki bazı potansiyel faydaların önemi de sorgulanmış ve katılımcıların bir proje yönetim yönteminin özellikle maliyetleri düşürme ve proje teslim süresini kısaltma açısından fayda sağlamasını bekledikleri görülmüştür. İleriki çalışmalarla CCPM yönteminin bilinirliği ve uygulamalarının artması durumunda bu potansiyel faydaların elde edilebileceği öne sürülmüştür.

Anahtar kelimeler: Kritik Zincir Proje Yönetimi, CCPM, Proje Yönetimi

Dedicated to my dear husband for his support in all chapters of my life and his patience with all my busyness and lack of time and to my precious family for always supporting me to "not give up" until the end.

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1.1. Background of The Research and Problem Statement

The rapid improvements in technology that are taken place in the recent past, have affected the daily life of individuals as well as the requirements that the companies must align themselves in order to survive in the market. Companies feel they have to adapt these changing dynamics.

Also, globalization in markets brought with it transformation needs in traditional business processes. Firms have to rethink and redesign their business processes and transform them from manual to digital. Digitalization (as being described in Gartner IT Glossary (Digitalization, https://www.gartner.com/en/information-technology/glossary/digitalization) : "use of digital technologies to change a business model and provide new revenue and value-producing opportunities") is one of the most popular topics in companies nowadays. It is the main KPI in many companies' annual strategic plans and 'being more technological' issue is seen as a big competitive factor. Companies are increasingly investing in digitalization.

But digitalization of a firm is not only being transferred from manual to digital processes, but also it means overtaking new challenges which transformation brings about (Fichman 2014). That's why in today's digital world, things get more and more complicated and hard to manage for firms. Transforming processes means a robust change in daily working routitines and employees do not always welcome "change" at all.. Often, employees in companies prefer to do their jobs in the way they are used to, and tend to resist changes in the systems, tools and ways of doing business in order to protect their comfort zone. So we can say, successful digitalization projects needs good change management.

Planning who should guide the people working in the institution and who will carry out activities that will increase their motivation are also among the responsibilities of the senior management of the companies, as sponsors. Companies hire professionals who are able to handle ‘the change’ Digital transformation requires to manage different parts of the company, ‘horizontally’ and ‘vertically’. This means working with lots of different people and make them complete tasks usually without being their manager and this is a situation that must be handled by project management professionals.

As a result of orientation to the changing environment efforts, companies’ business models, products, communication ways and market dinamics are constantly getting more complex. Complexity brings up with spesific information needs and complex operations. As a result of this; companies spend more money, effort and time to transform their systems and improve their work processes for better decision making, to get faster and more detailed information , higher customer satisfaction to achieve sustainable profit and to be able to survive in the market in the end of the day , at least…

As an example for the complexity matter; international companies want to integrate their applications with their offices in the countries where they operate. This is a challenging process that requires strong coordination, infrastructure feasibility studies and even analysis of cultural differences. It is almost impossible to conclude this process successfully without following structured and systematic management steps.

When we come to the point where it is an issue how to handle this complex and constant ‘actions’ within corporations, that effects different parts of the organization

in different levels, seeing the big picture and organising all instruments like an orchestra conductor becomes a huge need. Here “Project Management” discipline comes to the scene .

Enterprises start to hire professionals specialized on project management operations with the consciousness of knowing that managing a project differs than managing any other work and knowing that project management has the possibility of getting the company to success, in case of accurate management.

It can be said that; the ascension of the individuals holding a PMP certificate and also companies’ job advertisements that declare holding a PMP certificate as a key asset are signs that the increase of importance of the project management. Project Management Association (PMI) released the number of PMI certified project management professionals as 330.000 in 2009 and this means the number of certified PMPs amazingly increased in a decade as this number was just 27.052 in 1999. (PMI Today, 2009, https://www.deepfriedbrainproject.com/2009/04/pmi-fact-file.html) There are 432 PMP certified project management professionals according to the February 2016 data of PMI Turkey Chapter, in Turkey.

In corporate firms Project Management Offices (PMO) or Transformation Offices (TO) are being formed that are responsible for planning, implementation and monitoring of project management activities, tracking the project progress for the executive level from one center and help creating corporate memory in order to provide sustainability. Silva and Bouter (2015) mentions that establishing of Project Management Offices within corporations or planning to have one, has increased in the last ten years as a result of growing understanding of Project Management’s

importance widely and they emphasize the value of PMO's describing them as "enablers of organizational change".

Importance of Project Management caused a growing interest for research in this area to define main consepts and issues within managing projects. Morris et al. (2010) indicates the importance of project management research describing it as a research field which is not only supports the development of project management but also supports the effectiveness of companies and even industries.

Academicians and project management professionals have produced wide theoretical and practical knowledge in Project Management area. There are regular publications which includes research findings in this field , such as Project Management Institute (PMI)'s Project Management Journal and International Project Management Association (IPMA)'s International Journal of Project Management. This window shows us that the development of project management discipline is important not only for business professionals but also for the scientific and research community.

The diversity of approaches and implementations related to Project Management discipline is really impressive. This diversity exists in both academical and practical field. Some of the approaches are contradictory. Some of the researchers point out the lack of the theoretical discussions in the Project Management research field. For example , Pollack (2007) asserts that the theoretical basis of project management is highly "implicit" and there is no so much discussion on the theoretical basis of project management.

Also, as Sankaran and Tay (2007) mentions, there is a debate in the papers about relation between research and professional practice. As project environment is

a living and complex structure and as human nature involves in it, every theoretical approach may not be suitable for practical implemantations. So, another issue in Project Management is that : coherence between theoretical research and practical implementations. Even, the same approaches can even yield different results in different countries' cultures.

Discussions about the pros and cons of various approaches, methods and techniques have significantly increased. Beside these, how do we call a project 'successful' (what are the characteristics of project success), how can we evaluate a project's success and how a project's failure can be prevented are still just some of remaining discussion questions in this field.

Also, another question to be asked why project management were so popular while projects were failing. So many projects with large bugdets keep failing, but project management still sounds so interesting for academicians and professionals. Project management is still an outstanding research area; despite the growing consciousness for project management in corporations, projects kept failing… This means losing serious amount of time and money for the corporations. Standish Group have published a report called 'CHAOS Report' that is a big picture of the software development projects' success, every two year since 1994 and according to 2015's CHAOS Report which is an analysis of 50.000 projects' success state, only %29 of the projects were defined as successful. (The Standish Group, 2015) This rate means there is still need for improvement in project management research. But when we turn back to the 1994's CHAOS Report results, only %16 of the projects were defined as successful (The Standish Group,1994) It is seen that a significant way has been taken in the last decade…

As Geraldi et al. (2008) mentions, pursuit of the answers is a trace of this research field's "immaturity". There is a long way to go and lots of topics to discuss , also there are so many windows to look through as Project Management is a multi-disciplinary field and requires to undertand various aspects...

This thesis study investigates the techniques and approaches that found place in practice within corporations and in project management literature, with their pros and cons which are presented in academic research and experiences. Especially this thesis focus on 'Theory of Constraints-Critical Chain Project Management' approach which I couldn't find a firm that uses this approach regularly in our country, to conduct an action research, despite of it finds a broad place in international resources and broad implementation area in foreign companies. This thesis includes an empirical research that focuses on the 'existence' of knowledge and implementations of CCPM approach in our country aiming to light the way for future researches to be able to contribute the development of project management research and increasing the knowledge level of CCPM to benefit from its potential advantages in our country.

In a study conducted by Çırak (2013) it's been pointed out that there is a very limited amount of study about CCPM in Turkey. Also in a study by Tekin(2006), a previously scheduled plan in a company is re-scheduled using CCPM and an alternative project plan was developed and benefits of this method has been underlined, theoratically. Also Gürses (2007) who conducted a study about CCPM implementations, mentions in her study that there are no companies in Turkey using CCPM method. The only implementation case can be found in Turkey's literature is a hotel construction project that is placed in Sekreter's (2009) master thesis , but it is not clear that if the construction project has completely managed with CCPM principles or it is just a re-scheduling simulation. In her study Sekreter (2009) also

noted that there is no known implementation area of CCPM in firms in Turkey and only by some consultancy firms and by a limited number of researcher, a theoratical based inform is made about this approach.

Therefore, since the year 1997 the approach arises, only a few number of academical studies have been conducted about the subject and practical implementation case couldn't be found within them in Turkey. This study has been triggered by the lack of academic research and practical implementation in this area, in Turkey.

1.2. Research Objectives and Methodology

This master thesis is divided into four main parts, except for Introduction section. First part of the study is a literature review. As project management is an evolving and diverse area, it is not possible to look at all of the consepts of it, in such study, therefore a scope is defined for the literature review section.

In order to determine the scope, nine knowledge areas of Project Management which are defined in PMI's PMBOK has been examined as a start point and one of them, "Project Time Management" knowledge area is selected to focus as it includes approaches and techniques related to activies in Project Management. (PMBOK 4th Ed.,2008)

In other words 'Scheduling' issue of Project Management discipline is the basis of this research. In this section of the study, some of the best-known approaches and techniques related to 'Project Time Management' field which takes a place in the literature and used in the practical implementations have been reviewed briefly and there is a deeper look for one of them : Critical Chain Project Management, the main research topic of the thesis. Other than these are out of scope of the thesis.

The second part is research method and design description, which explains the details about survey research. Third part consists of a self conducted web-based survey's result analysis which is implemented to the project management professionals to find out answers for research questions. In this part, according to the survey answers, statistical test methods have been applied.

To be able to conduct spesific researches about CCPM implementations in our country and in order to present determination and suggestions, in my opinion, first of all most fundamental questions have to be asked. Starting from this idea, aiming to create a basis for upcoming higher level questions that will be asked and researches that will be conducted, these guiding research questions below are stated :

1. Is CCPM approach ***known in Turkey*** ?
2. Is CCPM approach ***applied in Turkey*** ?

After looking for answers to these questions, the relation that will be defined between this approach's knowledge and implementation, might cause studies and researches which will be conducted in the future about this subject, reaching different points .

For example; if it is known but it is not implemented, is this method not preferred, and which methods are used instead? If it is neither known nor used, then what can be done in order to increase it's recognation and make advantage of its benefits? Such new research questions may emerge.

Also, as a further question's answer is examined through this survey ;

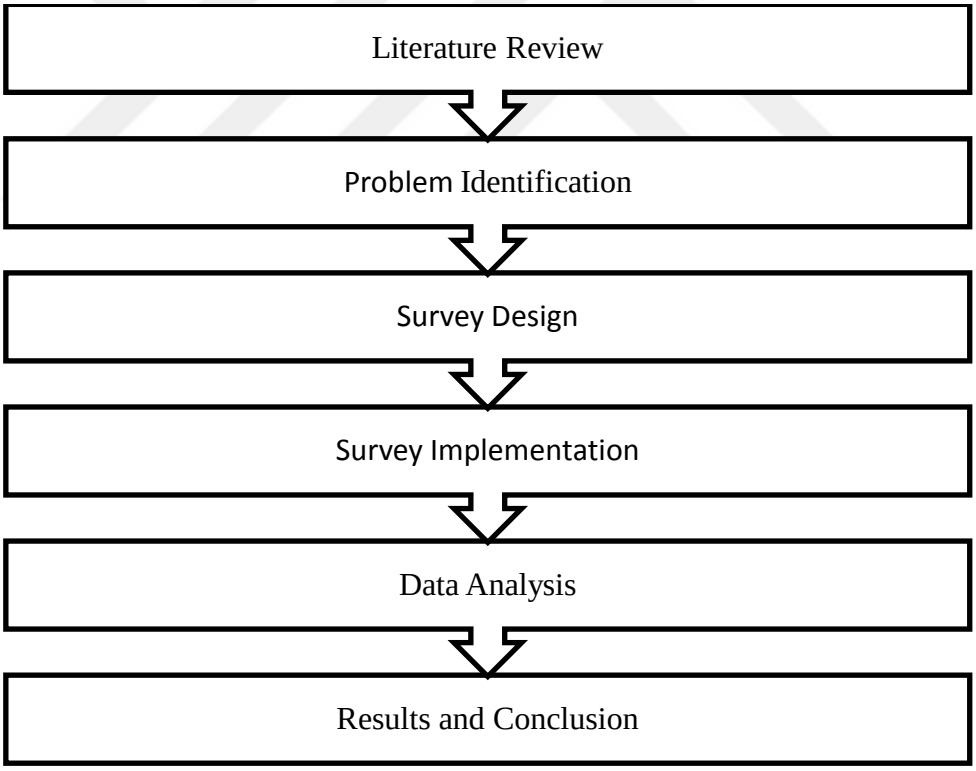
- Are the alleged potential benefits of the CCPM approach benefits that project management professionals consider when following a project management methodology?

In the final part of this study, results of the research and suggestions for further studies are stated, as conclusion.

The research methodology that is mainly followed in this thesis is illustrated below:

Figure 1.

Research methodology for this master thesis



2. LITERATURE REVIEW

2.1. The Term of 'Project'

The word 'project' comes from Latin 'pro-' with a meaning of "forward" and "iacere" which means "to throw" and their combination means "something thrown forth" (Online Etymology Dictionary, Project, https://www.etymonline.com /search?q=project It is obvious that, this word's meaning for people significantly changed through the years and it is now frequently used in almost every field ; production, construction, software development, education etc. Geraldi et al (2008) mention that , people have implemented projects since building pyramids and China's Great Wall and projects have been the key tools for the improvement of the community.

'Projects' are important topics of the business meetings that attract attention. Professionals constantly try to find fresh and innovative 'project ideas' for many purposes like shortening processes in their corporations, improving operational effectiveness, getting better customer experience to make profit in the end of the day...

This extensive usage of 'project' might be confusing in terms of understanding the essence of the word. In order to comprehend consepts within project management activities , it might be helpful to clarify a project's nature. A very well-known non-profit professional membership association, PMI (Project Management Institute) describes project as "a temporary endeavor undertaken to create a unique product, service or result" in their PMBOK (Project Management Body of Knowledge) guide. (PMBOK 4th Ed.,2008)

So, a project must have a definite begining and end point , also the results of this work must be different from anything that was produced by the corporation before (like a new software product etc.) (Horine 2009) So, a project can be recognised by it's temporariness and uniqueness. Because of unique characteristic, every new project means a new experience and challenges for the companies. A project would be terminated when the objectives of the project accomplished. But the project's objectives and boundaries must be clearly defined and agreed by all parties within the project management group.

It is a common mistake that some ongoing operational works in the companies are called 'project' and the person who manages this is called 'project manager'. Judgev And Muller (2005) states that because projects turns into a regular work model, the lines between projects and operational works are getting insignificant. Although, both projects and operations organised and managed by the employee of the organization, these two aspects have some differences inherently. For example, process of creating a machine prototype is a project but if it is successful and it is constantly produced and sold, this becomes an operation rather than a project.

In the *Table 1* below , there is a comparison between projects and operations that shows the points where projects differentiate from operations.

Table 1

Projects and Operations Comparison

Feature	*Projects*	*Operations*
Key Similarities	Planned, executed and controlled. Performed by people. Resource constrained.	Planned, executed and controlled. Performed by people. Resource constrained.
Purpose	Attain objectives and terminate	Sustain the organization

Time	Temporary Definite beginning and end points.	Ongoing
Outcome	Unique product, service and result	Non-unique product, service or result
People	Dynamic, temporary teams formed to meet project needs Generally not aligned with organizational structure	Functional teams generally aligned with organizastional structure.
Authority of Manager	Varies by organizastional structure Generally minimal, if any, direct line authority	Generally formal, direct line authority

Note. Adapted from "Project Management Absolute Beginner's Guide, Third Edition" by Gregory M. Horine, 2013, p.9, Copyright by Que Publishing.

2.2. Project Management :

After clarifying what is a project and what isn't, 'project management' can be defined as ; "the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements." (PMBOK 4th Ed.,2008) Project management is a 'subdiscipline' of Operation Research (OR)

McGhee and McAliney (2007) describes project management as "The processes involved in managing a project that requires the application of planning, team building, communicating, controlling, decision making, and closing skills, using specific tools and techniques". Then it can be said that; a project manager, as a person who is responsible to manage the project activities like an ochestra conductor, must have these skills. Just like a violin virtuoso cannot always be expected to conduct an orchestra very well, we cannot say that a very good software developer or analyst will definitely be expected to be a good project manager.

Project Management, has different definitions in the resources. But maybe the simplest and easy to understand for everyone is, Widemann's project management definition : "the underpinning of project management can be characterized as 'getting

things done' " (Widemann,1995) But he also adds to his definition, stating the role of interpersonnal skills, unlike many others, it is about "manner of how people do it". Human factor highly effects project management activities, because the main 'resource' of the projects is human. The consepts and components of projects can not be fully understood without considering human nature and it's complexity and uncertainity..

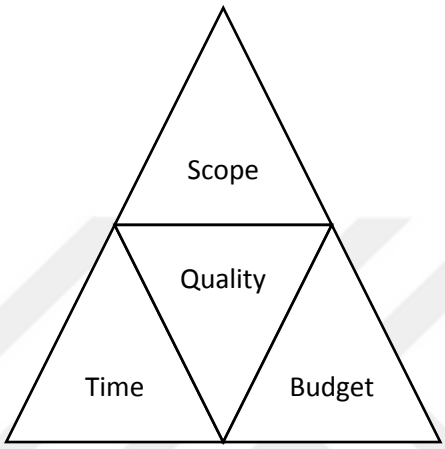
There is an interesting approach to Project Management in The City Of Chandler's PM Methodology Guideline. The document supports that Project Management is both "science and art". Science because of including systematic appoach and standard methodology, and also an art because of "soft skills" involving in it, which is being improved through experience like problem solving, managing etc.. (The City of Chandler, Project Management Metholodology Guideline) Project Management is open this kind of discussions as there is no generally accepted assumptions about it's nature and this is a seperate research topic.

In the traditional resources about Project Management, it is common to see the famous "iron triangle" (Atkinson, 1999). This triangle shows the main points to focus in the Project Management activities, in other words 'main constraints' and the project managers are supposed to always keep in mind these components of the triangle: time, scope, budget and the quality in the center as fourth constraint. It is used to show that a project's success is evaluated by getting expected results while managing cost and time and if one of these factors is changed, the others will be effected (Newell & Grashina, 2004) For example, if we want to complete the project in a shorter time than defined before, then we must spend more money for more resources and if we try to finish it with less time and less budget, then quality will be

low, as a consequence. Similarly, if we want to expand the scope, we will have to spend more money and time to finish extra work that new scope brings.

Figure 2

The Iron Triangle of Project Management



As project management culture and experience increased, researchers and professionals have gained different aspects about constraints within project management. Judgev And Muller (2005) emphasise that recent definitions (for constraints) are wider as indicating the importance of the role of the stakeholders in terms of needs, expectations and tasks.

PMI divides processes that is executed in a project into five process groups : (PMBOK 4th Ed.,2008) “Initiating, planning, executing, monitoring and controlling, closing”. In the same resource, it is emphasised that a process group is not a phase of project and as projects are divided into different phases such as design, build, test etc., each of these process groups must take place in each phase. (PMBOK 4th Ed.,2008, p41)

Project management is a multi-dimensional management discipline as different knowledge areas involves in it. PMI identifies nine seperate knowledge areas for project management (PMBOK 4th Ed.,2008) :

1. Project Integration Management : Consists of processes which is required to integrate different components of project management process groups, starting with developing of the project charter.
2. Project Scope Management : Consists of processes which are about project's scope, such as defining scope.
3. Project Time Management : Consists of processes which are about scheduling. (including defining 'tasks' within the project)
4. Project Cost Management : Consists of processes which are about budget (estimating, controlling etc.)
5. Project Quality Management : Includes the processes that are about achieving the quality.
6. Project Human Resource Management : Includes the processes that are about 'human' side of the project.
7. Project Communication Management : Consists of processes that are about information flow within the whole parties of the project.
8. Project Risk Management : Includes the processes which are about project's risks.
9. Project Procurement Management: Includes the processes which are about 'buying' everything that is needed for the project.

2.3. History of Project Management :

Altough, it's name was not 'project management' in those years, and being a project manager wasn't that popular, project management implementations are as old as the ancient cities of Mesopotamia and pyramids of Egypt. Seymour and Hussein (2014) indicate that there are so many successful project examples in history, despite being so complex with large budgets, huge resources, very long work times and having uncertainities that could be enough to cause failure of a project. Also they mention about having very few documents about these ancient projects' methods and techniques. (Seymour & Hussein , 2014)

Modern project management techniques has began to be implemented in 1950s, so it can be said that project management is a young field. But before this, Henri Fayol (1841-1925), a French Engineer, came up with "five functions of management in 1916: planning, organizing, commanding, coordinating and controlling". (Kwaak,2003) Henry Gannt (1861- 1919) ,an American engineer, developed 'Gannt Chart' and this chart was used in the big projects during the World War 1 and also used in construction of Hoover Dam and it still in use today, as an important project management tool and Fayol and Gannt are known as the forefathers of project management (Seymour & Hussein, 2014)

According to Morris et al. (2010), "the language of modern project management" is invented in early 1950's and in their book 'The Oxford Handbook of Project Management' it is mentioned that The Manhattan Project (a project to make the Atom Bomb) is often seen as one of the first modern project management implementations, despite there was no modern tools or techniques of project

management in it. Then, in 1953 project management began to appear as a term , in the US defense sector (Morris et al. , 2010)

A project called ‘Polaris’ was applied by U.S Navy in 1958 and in this project U.S. Navy created one of the most known techniques today ; PERT (Program Evaluation Review Technique) and this thechique was suitable for the project’s various schedule scenarios. (Seymour & Hussein, 2014)

Stretton (1994) summarizes the developments in project management in 1950’s as emerging need for assignment a project manager to take complete responsibility to reach the project purposes and developments in network techniques.

Another important development was in 1960’s , the use of Work Breakdown Structure (WBS) approach which is “ the process of subdividing project deliverables and project work into smaller, more manageable components” (PMBOK 4th Ed.,2008)

Also, with the foundation of first project management association, International Project Management Association (IPMA) in 1965 and Project Management Institute (PMI) , the editor of The Project Management Body of Knowledge (PMBOK), in 1969, “institutionalization” era of project management started (Seymour & Hussein, 2014)

In 1960’s and 1970’s NASA and other big construction companies implemented project management techniques to undertake large projects and in 1980’s manufacturing and software companies began to use applications of project management and finally in 1990’s these techniques and tools were highly used by various sectors. (Kwaak, 2003)

In 1975, a project management method called 'Project Resource Organization Management and Planning Techniques (PROMPTII) was developed by Simpact Systems which was later turned into 'PRINCE' (Projects in Controlled Environments) and finally 'PRINCE2' and it was used as standard methodology for English Government's information system projects. (PRINCE2 - A Structured Project Management Methodology, https://www.prince2.com/eur/prince2-methodology)

With the Eliyahu Goldratt's novel '*The Goal*' in 1986 , a management philosophy 'Theory of Constraint' (TOC) came to the scene and in 1997 Critical Chain Project Management (CCPM) method was derived from TOC with his novel '*Critical Chain*'. But before CCPM, other techniques were developed such as Scrum (an agile develepment method) in 1986 and PRINCE2 in 1996. (Seymour & Hussein, 2014)

PMI released the first version of PMBOK in 1986 in the Project Managment Journal (Stretton,1993). Stretton (1993) mentions that there was an interest for "external factors" of project environments, during 1980s.

To have a better understanding of project management evolution and see the big picture , it may be useful to look at Kwaak's (2003) four seperate "periods of project management history" that he divided and summarized as below;

1. Prior to 1958 (between 1900s and 1950s) there was a transformation in project management from "a Craft system to Human Relations Administration"
2. 1958- 1979 there was important technological improvement and this period was an "application of Management Science"

3. 1980- 1994 : “Production Center : Human Resources” Project management application for PC was available and project management techniques were easily accessed.
4. 1995 to present: “Creating a new environment” With the Internet, information technology revolutionized existing business models and different industries started to implement project management techniques.

This can be said that we are in a period of time, that project management applications are wider than ever and this is the most prolific era in terms of project management cases in various industries…

2.4. The Project Life Cycle :

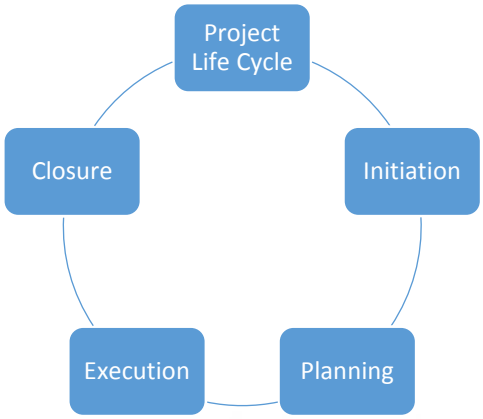
One of the definitions of the project life cycle is ; “the sequence of activities running from the time that the project is initiated to the delivery of project product to the final user or owner” (Pica,2016)

All projects, regardless of how extensive or complex they are, have a life cycle made up of various series of activities. Although different approaches are encountered in the literature, usually there are 4 phases defined as project life cycle phases (Westland,2006)

This chart below shows these phases of the project life cycle :

Figure 3

The Project Management Life Cycle



First phase is initiation phase and in this phase, business problems and possible solutions are discussed. But how how a project starts is a different matter from project to project and even from company to company. There is an interesting term in one of the most known project methods' guide book, PRINCE2 about this ; "project mandate" and this term represents "trigger" (Butterworth & Heinemann, 2010) . This trigger may be a brief that is given to the project manager, or a detailed analysis or even just a verbal demand.

In this phase, expected results and key success factors are determined (Wong et al , 2018) All prioritization work (output, expectations, benefits etc.) is carried out in this phase. On the other hand, with the feasibility studies to be carried out in this phase, the compatibility of the estimated costs with the output expectations, number of the possible solutions and which of the solution alternatives produced for the needs are more suitable for the purpose, whether the identified possible risks can be taken, and whether the targets are attainable are determined (Westland,2006). Also in this phase, if PMBOK project management methodology will be used, a 'project charted' (a project document that explains what to achieve as a project output) is prepared.

There is a similar project document as ‘brief’ in PRINCE2 approach (PRINCE2 Project Brief, https://www.prince2how2.com/2014/12/prince2-project-brief-template.html)

Aaltonen et al (2008), draws attention to the importance of the initiation phase of the project, claiming that it is an important handicap for the success of a project not to have a complete agreement between the people who manage the project and the senior management regarding the possible outcomes of the project from the beginning (Altonen et al, 2008). Senior management's support as sponsors is critical to the success of project management, and it can be difficult to get support in the later phases if an exact buy-in is not achieved for sponsors in the initiation phase. This situation may become a factor directly affecting the total success of the project.

After initiation phase, planning phase comes. In this phase, whole roadmap of the project is drawn. It is a critical phase that will affect the fate of the whole project as it is necessary to decide which of all the tasks and sub-tasks will be completed and in what order. Imagine that a ship with a wrong route can never dock at the right port and on time. If the right planning is not carried out at this stage, there is a risk that what will be done in the next implementation phase will be wasted. In this study, the focus is on approaches considering the planning phase of a project life cycle, as the planning phase has an undeniable importance in project time management.

There are some main activities that must be completed in the planning phase and according to Westland (2006) , these activities must be in a sequence like below ;

Create project plan ➔ Create a resource plan ➔ Create a financial plan ➔ Create a quality plan ➔ Create a risk plan ➔ Create an acceptance plan ➔ Create a

communication plan ➔ Create a procurement plan ➔ Contact the suppliers ➔ Perform phase review

This set of activities appears to include action in the planning phase related to most of the project management knowledge areas (which listed before) expressed in PMBOK.

Risks and constraints are also defined in the planning phase and other necessary documentation work (schedule, work breakdown structures etc.) is completed. All instruments to be used in the next phase and all necessary calculations and estimations (cost, timing, resource needs, training needs) are completed in this phase.

After planning phase is completed, execution phase starts. This phase is the phase in which all the works planned within the scope of the project are carried out and the plans are implemented. During the execution phase, the risks that arise as the activities are completed are measured and in case of situations that do not comply with the plan, new risks are determined and added to the plan (University of Minnesota, 2016)

The closeout phase comes after the execution phase. The closeout phase is the last phase of a project. In this phase, results of the projects are delivered to the client and task lists are completed, project teams are transferred and all the paper work of the project is recorded. (University of Minnesota, 2016) Some project team members may be temporarily hired for the project and this kind of staff agreements are terminated in the closeout phase.

2.5. Approaches in Project Management Activities:

A question can be ‘Why do we need to use methods in project management?’ Uniqueness is one of the characteristics of a project, so if it is unique, it may be

thought that there should not be a method or technique that is suitable for all projects and we must create one to fits our project. But the main components and constraints of a project are similar with other projects indeed. These are the features that makes a work called a project ; there will be activities, scheduling issues related to limited time, bugdet and scope issues , stakeholders and sponsors to satify, human psychology factor, multi-tasking problems etc.. So there must be some useful methods and techniques that has been used before, in projects that have similar features as ours and could be beneficial to use them. If a project manager doesn't follow a known-way, then must create his/her own way to manage the project and this means to solve the problems following an informal process of trial and error and this method is not very effective for project environment.

'Scheduling' is one of the main focus areas for project managers, as it is about to manage time and losing time means losing money , in a project environment. In other words, wrong scheduling can be very expensive for the company. The importance of a correct schedule plan in terms of project's success is highlighted by researchers like Dursun and Stoy (2011)

In this chapter, some approaches and techniques about the scheduling project activities have been reviwed.

2.5.1. 'Activity' in a project:

An 'activity' is the core element for scheduling. In the resources, 'activity' and 'task' terms are used to refer each work part to be completed in a project. In other words, an 'activity' in a project is "the smallest discrete block of time and resources typically handled by PM software" (Activity, blog.bizpro.com.tr/proje-yonetimi-sozlugu) According to PMI, to define activities is the first stage of the 'Project Time

Management' knowledge area and it is defined as : "The process of identifying the specific actions to be performed to produce the project deliverables." (PMBOK 4th Ed.,2008, p.129)

As mentioned earlier, this research focuses "Project Time Management" as project knowledge area. Heldman and Mangano (2011) gives a list of six processes and process groups which form Project Time Management;

Table 2

Processes of Project Time Management

Process Name	***Project Management Process Group***
Define Activities	Planning
Sequence Activities	Planning
Estimate Activitiy Resources	Planning
Estimate Activity Durations	Planning
Develop Schedule	Planning
Control Schedule	Monitoring and Controlling

Note Adapted from "Project Time Management" by K. Heldman, V. Mangano, 2011, *PMP: Project Management Professional Exam Review Guide*, p.16 , Copy right by John Wiley & Sons.

In order to keep track of a project's completion time, it is required to prepare a detailed schedule of whole activities of the project and control the process according to this schedule (Field & Keller, 1998). All activities of a project must be listed in the 'Work Breakdown Structure (WBS) ' that is created by the project team to show which works to be done within the project scope and who will be responsible to complete them, as a list.

According to Marchewka (2016), it will be important to comprehend the relationship between activities, project team and schedule to be able to handle amendments in further planning or money issues.

There is an interrelationship called ‘dependencies’ between activies. If an activity starts as soon as after another activity is completed, then this first completed activity is called the ‘predecessor’ of the other one. This means, completion date of an activity is depends on when its predecessor is completed. Predecessor activity’s next activity is called ‘successor’. For example, a software application can not be tested before it has been coded. Then, ‘coding activity’ is the predecessor of ‘testing activity’ and the testing activity is the successor of coding activity. Also, there are ‘parallel’ activites which are independent and can start at the same time. This dependency between activities is the main consideration point in the estimation of the project’s completion time and one of the major components of a project schedule.

There are various scheduling techniques in the literature and practical field of project management. Two of the today’s best-known and widely used techniques Critical Path Method (CPM) , Programme Evaluation and Review Technique (PERT) and their precursor ‘Gantt Chart’ is reviwed in the next section of the study.

2.5.2. Gantt Chart :

The question that probably every project manager encounter is how many times it takes to complete the project. As project’s completion time is vital for budget estimations, seeing the picture of project duration is the issue of all times for project management. This issue brought about developments in this area. Gantt Chart was developed by Henry Gantt, who is known as one of the forefathers of project management, in coordination with U.S. army (Marchewka, 2016) , in earyl 1900’s and it has turned into the most widely used method for illustrating a project schedule

(Verzuh, 2005). It is also called ‘bar chart’. Seymour and Hussein (2014, p.235) indicates that, Gantt Charts are outstanding for project management’s history because they have revealed the advantages of seperating the projects into smaller manageable activities.

PMBOK defines Gantt Chart as a tool which is “a typical bar chart schedule activities or WBS components are listed down the left side of the chart, dates are shown across the top, and activity durations are shown as date-placed horizontal bars” in its glossary. (PMBOK 4th Ed.,2008, p.436)

Verzuh (2005) indicates that, the benefit of Gantt Chart is its clearness as it shows the schedule and WBS in the axis. Gantt Chart’s biggest advantage is visual illustration that makes understanding and monitoring the schedule easier. Also it takes a little time to create it with a common software such as Excel and this is another advantage of it. Beside these, Gantt Chart is suitable to use in small and basic projects with a small number of resources to define and monitor projects, but it has disadvantage in large and complex projects as it is diffult to illustrate the relationships. Also, Gantt Chart doesn’t show critic points or risks in project schedule specifically and this is another disadvantage of using it.

The steps of developing a Gantt Chart is described as below according to Basu (2004) :

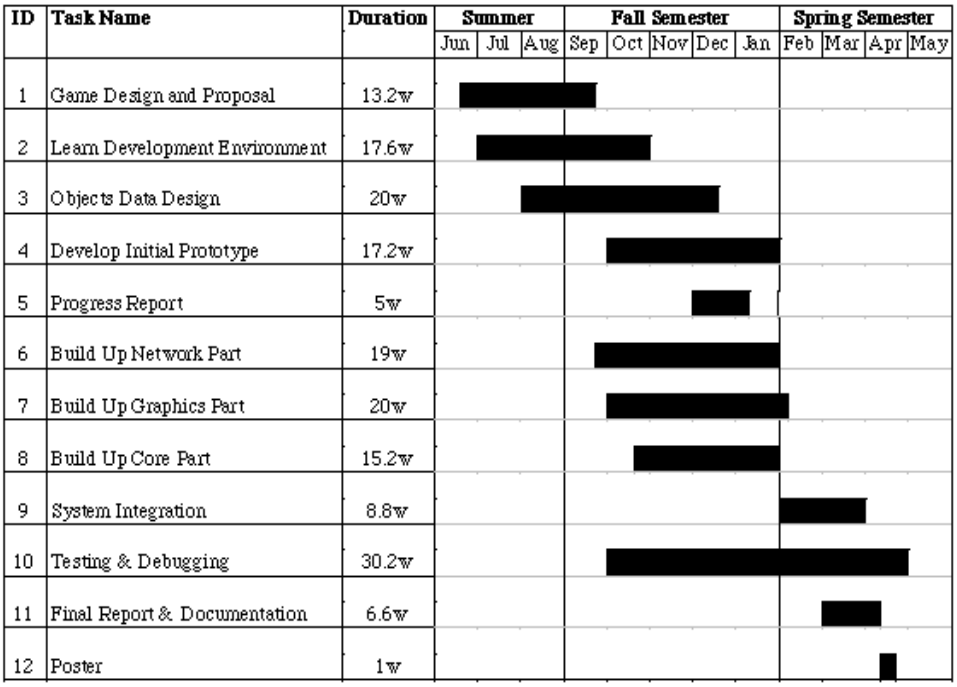
1. Defining activities within the project, describing them with the key words.
2. Creating a schedule board and drawing vertical lines for the division of the board according to project’s duration (daily, weekly or monthly)
3. Putting the activities in a sequence by start date estimation and locating them on the very left column of the board.

4. Estimating the start and finish times for each task and drawing horizontal bars (or lines) to show the duration of each task.
5. On the completion of tasks, indicate the actual start and duration with a different coloured bar for each task.
6. Locate a marker on chart which shows the current state and monitor and maintain the chart along the project.

There is an example illustration of Gantt Chart below in the *Figure 4*

Figure 4

Gantt Chart Example



Note. Taken from *The Hong Kong University of Science and Technology,* *https://www.cse.ust.hk/~fred/FYP/Network-3Dgame/Requirements/Gantt-example1.html)*

2.5.3. Critical Path Method (CPM) :

Critical Path Method is one of the best-known scheduling methods. It is widely used in various industries today. In our country, it was used in 'Marmaray Project'. Critical Path Method was developed by Du Pont de Nemours and Remington

Rand in 1957. Valikoniene (2014) indicates that, according to the history, creating CPM is a result of a pursuit of an "optimum" schedule , considering cost and time in engineering and constraction projects.

PMBOK definition of the CPM is "A schedule network analysis technique used to determine the amount of scheduling flexibility (the amount of float) on various logical network paths in the project schedule network, and to determine the minimum total project duration" (PMBOK 4th Ed.,2008, p.431) It can be explained as an approach that seperates the project into activities, shows these activities in a flow chart, estimates the project completion time based on each activity and identifies activities which are critical in terms of project completion.

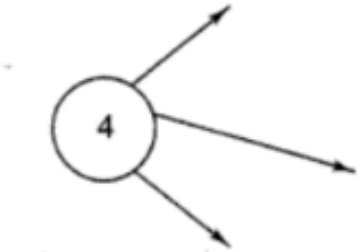
In Critical Path Method, first step is the identification of activities within the project and dependencies. It is the basic assumption in CPM that, each activity's duration is already known in terms of hours, days or weeks. This means it is assumed that there is no need to estimate activity durations to conduct CPM.

CPM is method defined as '*network* analysis technique' above. A *network* is a representation of activities and events in a project environment by nodes and arrows. In other words, it is diagram which is consists of nodes (generally circle or rectangular shapes) and arrows. The activities are arranged considering dependencies (predecessor-successor relationships), in the network diagram. There is always an activity which has no predecessor and it is called 'start activity'. Start or finish of activities are called 'events' and there is only one activity between events. In network diagrams 'start' and 'finish' or 'end' events are represented on the two edges of the diagram.

When an event cause more than one activities get started, this is called a "burst" and when more than one event causes to start only one activity this is called "merge event" (Sivarethinamohan, 2008, p.417)

Figure 5

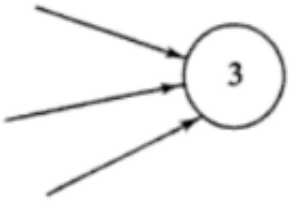
Burst example



Note Taken from *"Operations Research"*, R. Sivarethinamohan, 2008, p.417, TataMcGraw-Hill Publishing,

Figure 6

Merge event example

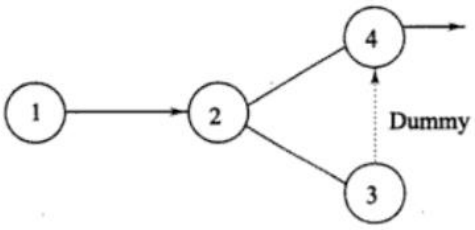


Note Taken from *"Operations Research"*, R. Sivarethinamohan, 2008, p.417, Copy right by TataMcGraw-Hill Publishing.

The activity type that represents only a "link between events" and doesn't any use resources is called "dummy activity" and they are sembolised with "dotted lines". (Sivarethinamohan, 2008, p.417) Dummy activities have no effect on the project's completion time. It is only used to provide logic.

Figure 7

Dummy activity example



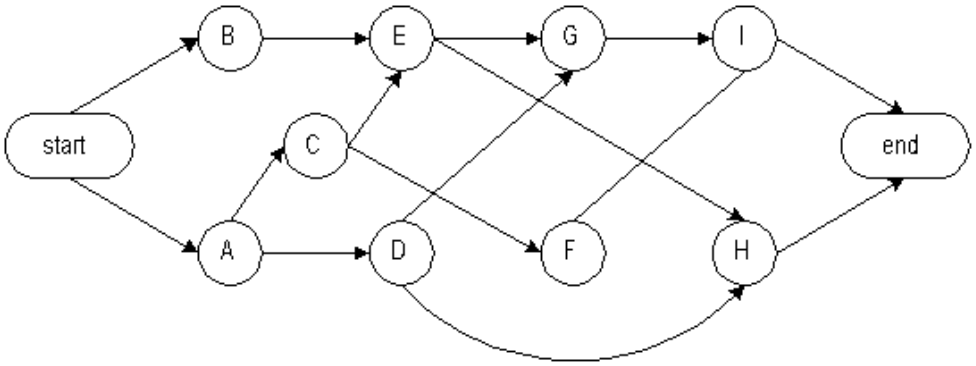
Note Taken from *"Operations Research"*, R. Sivarethinamohan, 2008, p.417, TataMcGraw-Hill Publishing.

In CPM, each activity is represented by a 'node' and the precedence relationships are represented by arrows in the network diagram. (Gümüşoğlu,1997) This type of representation is called 'Activity on Node (AoN) Diagram'. In AoN diagram, every node has a number or letter which is given generally consecutive to ensure the understanding of activity sequences.

There is an example of 'Activity on Node' Diagram that shows the network of a project which includes nine activities, below :

Figure 8

Activity on Node Diagram example



Note Taken from *Construction Planning*, Carnegie Mellon University, (*http://pmbook.ce.cmu.edu/09_Construction_Planning.html)*

After, network structures are clarified, the steps of CPM which is a technique based on networks can be defined as below ;

1. Identify Project Activities : This is the first and most important step of the planning phase because the whole network is based on these activities. Among many of activities, the activities that fits the project plan in details must be selected. To define activities, work breakdown structure can be used (Karadeniz,2007) as main input.
2. Define the precedence relationship between activities : According to the completion sequence of the activities, the relationship between them (predecessor, successor or paralell) must be defined. (Karadeniz,2007) The questions to ask must be ; which activity comes before , just after and at the same time with this activity.
3. Develop Network Diagram : The network diagram is created using activities and their precedence relationships which are identified in the previous step. (Karadeniz,2007) There are various softwares which creates network diagram automatically. It is also can be drawn on paper manually too but it is not very practical in case changes are needed.
4. Assign resources to activities : It is vital to know the current state of the resources (in terms of human and bugdet) for the project and these constricted resources must be distributed to the activities wisely. (Karadeniz,2007) The number of available human resources, their background and capabilities are important factors while assignment. Also there are some simulation techniques

5. Estimate activity durations : The resources that are assigned in the previous step are the main deterministic factors for activity duration estimations. It is important to conduct realistic estimations ; neither so optimistic nor so pesimistic estimations suggested. Because these estimations for each task affects the whole project's completion time estimation. (Karadeniz,2007)
6. Identify the critical path : Using the relationships between activities and durations, critical path and the completion time of the project can be found making calculations. (Karadeniz,2007)
7. Monitoring critical path through the project. (Karadeniz,2007)

If an activity have zero 'float' it is called a critical path activity. Float (or slack) means delay which can be accepted as it doesn't cause a delay in the project's completion time itself. The critical path is the activity sequence which has no float and causes delay in the project's completion time if a delay occurs in this sequence (Heldman & Cram, 2004). It is also the longest activity sequence. To make this calculation, "four parameter for each activity" must be defined (Critical Path Method, https://www.tutorialspoint.com/management_concepts/critical_path_method.htm):

- Earliest Start Time (ES): The possible earliest time for an activity to start, as soon as after the predecessor activity finishes.
- Earliest Finish Time (EF) : The time found adding duration of the activity to earliest start time. 'EF' of an activity is also equals to 'ES' for the successor activity.
- Latest Finish Time (LF) : The latest time that an activity can finish without causing delay in the project's completion date.

- Latest Start Time (LS) : The time that is found subtracting activity duration from LF

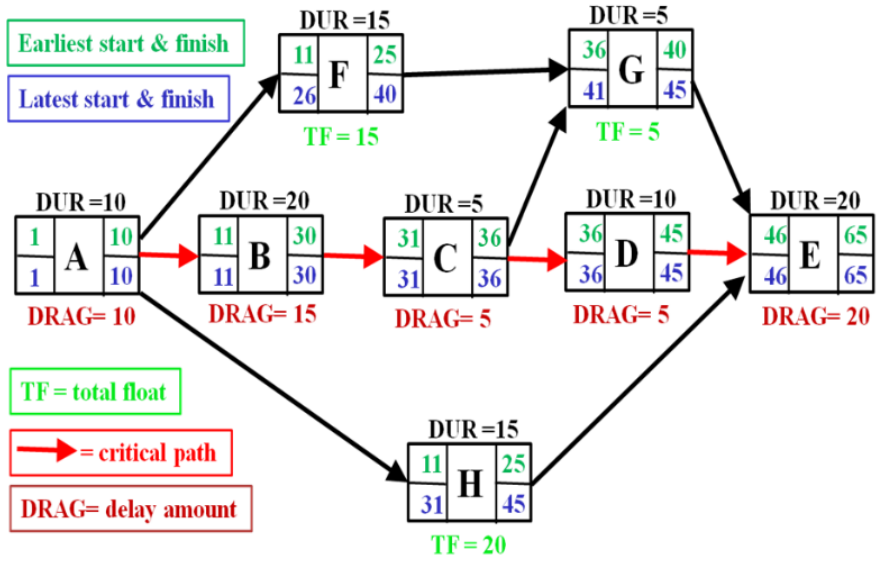
Today various softwares are used to calculate the critical path. To do it manually, there are three steps that are used in scheduling (Heldman & Cram, 2004) ;

- Forward pass computation : A "forward pass through the network diagram " is the first thing to define the critical path. ES and EF are calculated for each activity moving from left to right, until reaching the 'finish' event.
- Backward pass computation : This time, starting from the finish event, LS and LF are calculated passing through from right to left until reaching 'start' event.
- Float and slack time computations : Finally, 'float' for each actvity is calculated. It is calculated by using substraction of ES from LS or EF from LF for each. As critical path consists of activities with zero float, the combination of activities with zero float in the network can be determined as the critical path.

For example, in the figure below, the critical path consists of Task 1, Task 3, Task 5, Task 4, Task 7 and Task 9 activities on the network diagram. This means if any delay occurs on these tasks, project's completion time will be delayed too. But, Task 2 has 9 units float and this means Task 2 can be delayed up to 9 unit of time (days,week etc.) without affecting the project's completion time.

Figure 9

Critical path determination example



Note Activity-on-nod diagram showing critical path schedule, along with total float and critical path drag computations. Taken from *Critical Path drag*, *https://www.wikiwand.com/en/Critical_path_drag*

After calculating project's completion time analysing network, a finish date is revealed for the project. Sometimes customer or sponsors of the project may not be satisfied with this date and it may be required to finish earlier. At such time, project manager has various options to reduce the completion time of the project. Some of the solutions that can help to complete the project earlier than estimated are listed below : (Kerzner, 2009, p.510)

- Extraction of some activities from the project
- Assignment of extra resources
- Reduction in the critical path activity durations
- Reduction in the early activity durations
- Making some of the activities concurrent

- Reduction in the longest activity durations
- Reduction in the activity durations which are not expensive to expedite.
- Reduction in the easiest activity durations
- Adding more working time to the schedule for each day.

Purkayastha (2011, p.69) asserted that CPM's advantage is giving a chance to define critical activities, the activities next to them and the activities that are not critical so it is easier to see the 'threats" for the project duration. When a project manager knows where the danger exists, then he/she can be more careful in that points. For example, if a task's completion is delayed which is on the critical path, this situation can be monitored and then extra actions can be taken to expedite the other activities in the critical path in order to provide a shorter completion time for them, adding extra resources to them etc., to prevent a delay in the project's finish date.

But also there are some disadvantages of CPM. As it was mentioned before, it is assumed that the activity durations are already known before developing the network diagram, in CPM. But in the real project environment, it is not always possible to conduct accurate estimations for the activity durations. These durations can be affected by various external factors that can not be known before. There is human factor involed in these activities and this factor's complexity and uncertainity would be a criteria for activity duration estimations.

Beside this, Thompson (2013) indicates that, resources are planned in the schedule as if they would be "available" during the execution of the project but generally the state of the resources changes, especially in the large projects, after planning and this means change in terms of critical path. In this situation that he mentions, one of the advantages of CPM , knowing critical activities is become a

challenge as the critical activities on the critical path are constantly changing. Because it is become an issue to keep the critical path under control.

2.5.4. Programme Evaluation and Review Technique (PERT) :

PERT was developed in the same time period as CPM ,but independently. In 1958, U.S. Navy developed this technique for their Polaris project, as a scheduling solution against the "complexity and uncertainity" of this project (Seymour and Hussein, 2014) This project was a 'missle system' development project with a huge amount of activities involving and since this project, in many projects like Polaris that have uncertainities, PERT has been known as a beneficial technique. (Sharma, 2006, p.2)

Valikoniene (2014, p.36) asserts that; as CPM and PERT are techniques that have "similar" features with same pros and cons , they have become to be called CPM/PERT. In some books and research papers these two names are used interchangeably. Sharma (2006, p.7) indicates that one of the benefits using 'CPM/PERT' is enhancing task distrubition and thus providing better coordination between various business parties within the project. There are three consepts of PERT which are different from CPM (Sharma, 2006, p.25-26) :

- Optimistic Time (***o***) : Refers to "minumum possible" duration of an activity if optimum conditions are met (if there are no unexpected situations occured etc.) But this possibility is very low , such as %1.
- Pessimistic Time (***p***) : Maximum duration of an activity if the worst conditions (except for natural disasters) are occured. This estimation has a very low possibility as optimistic estimation.
- Most Likely Time (***m***) : Expected duration of an activity if pre-identified (expected) conditions are occured.

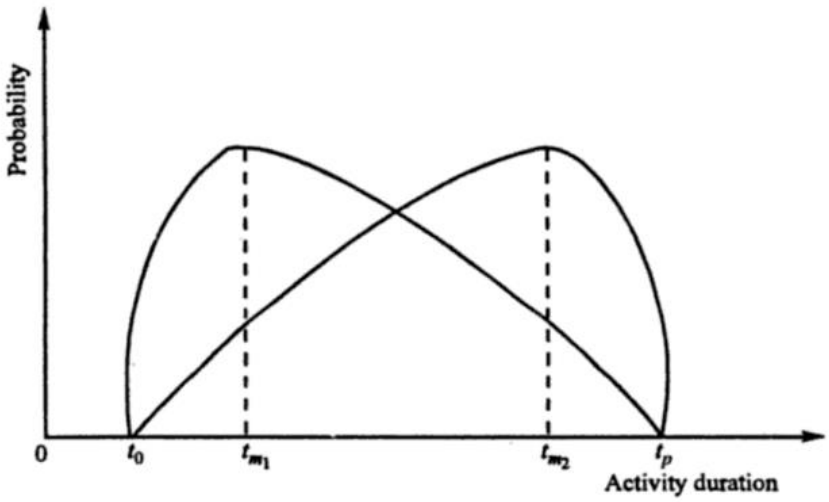
There is the calculation formule of the estimated completion time of an activity which is “a weighted average by equation” (Valikoniene (2014, p.36)

$$T = \frac{p+4m+o}{6}$$

According to these definitions, estimated time of each activity (T) must between (*o*) and (*p*) Most likely time (*m*) is either equals to (o+p)/2 or closer optimistic time or pessimistic time. It is accepted that, according to these three probability , “each activity follow a β (*beta*) distrubition”. (Sharma,2006, p.38)

Figure 10

Beta Distrubition Example



Note. Taken from *“Operation Research PERT CPM and Cost Analysis”* by S.C. Sharma, 2006, p.38, Discovery Publishing House

After estimating activity durations, using the same way as CPM , the critical part is defined. To calculate the project’s completion time , it is required to calculate critical path’s lenght and variance and the project’s duration can be estimated by

adding the estimated durations of each critic activity (Sharma, 2006, p.38) Activity variance is calculated by using this formule :

$$\sigma^2 = \left[\frac{1}{6}\left(t_p - t_o\right)\right]^2$$

Also standard deviation of each activity is :

$$\sigma = \left[\frac{1}{6}\left(t_p - t_o\right)\right]$$

After the variance is calculated for each critic activity, project's variance can be calculated adding critic activities' variance (Sharma, 2006, p.38) After defining the variance and standard deviation of the project's duration , the 'probability' of project's completion by a specified time (Z) is calculated via the formule below :

$$Z = \frac{T_d - T_e}{\sigma}$$

T_d = Specified completion time (i.e. customer's demand, deadline)

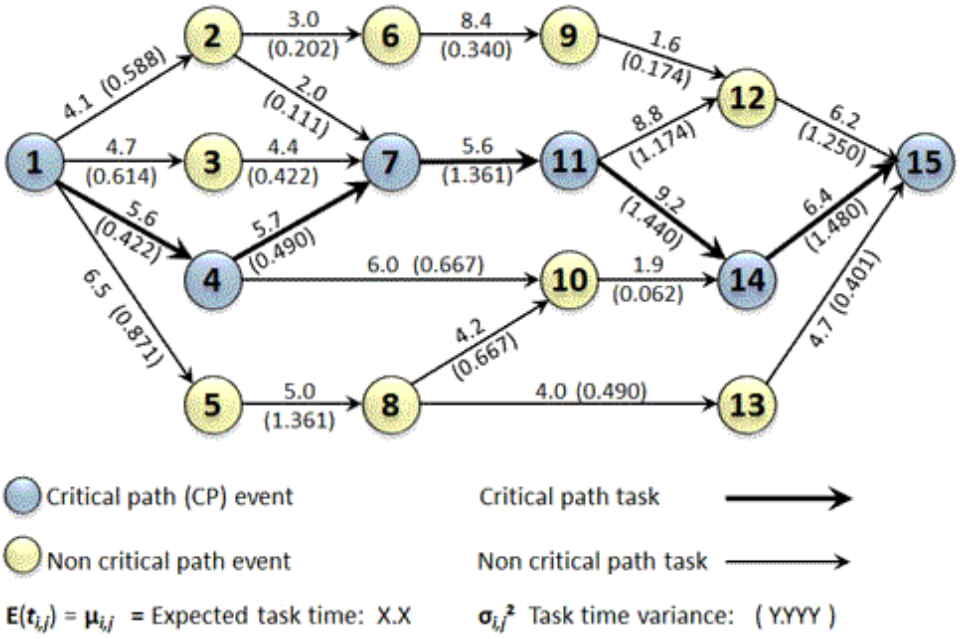
T_e = Expected completion time which is found by network analysis

σ = Standard deviation of the project completion time

There is an example illustration of a PERT calculations implemented network,including critical path 'events' :

Figure 11

PERT diagram example



Note. Taken from *Example PERT Network With Critical Path for Progress Tracking,* *https://www.business-case-analysis.com/schmidt-project-progress-chart.html*

Although, these two techniques are commonly known together, there are some approaches about the points where CPM and PERT differantiate from eachother. Some of them are listed below :

- As PERT estimates a “probability distribution” for the completion times of activities, calculations for each activity are required. (Sharma, 2006, p.5-6) But in CPM, it is assumed that the activity durations have been already known according to past implementations.
- In PERT, estimations are taken into account based on events, thus PERT is “event oriented” , while in CPM estimations are taken into account based on activities and it is “activity oriented”. (Sivarethinamohan, 2008, p.433)

- There is not a consideration of “cost” in PERT and “it is time oriented”. But as CPM creates a bound between “cost and time” , “it is cost oriented”. (Sivarethinamohan, 2008, p.433)
- PERT is suitable for projects that includes activities which will be performed for the first time and “non-repetitive”. (Sharma, 2006, p.5-6) (For example, building a bridge for the first time) So this technique doesn’t require former experience. But CPM is suitable for projects with formerly performed activities as it is required to know activity durations.

In the books and research papers, researchers widely discuss about both CPM and PERT’s disadvantages. They are both old and currently used methods but this doesn’t change the fact that they are problematic in someways. Hillier and Lieberman (2000) indicates that a research has shown that the PERT’s “approaximating the means and variances” of activity completion times gives a very rough result which is not very accurate. Because, ‘extremes’ of the distrubition are optimistic and pessimistic time estimations but these are very low possibilities. (Hillier & Lieberman, 2000, p.510)

Trietsch and Baker (2011) asserted that PERT is “uncalibrated” in terms of implementation. Also, CPM/PERT assumes that each activity will have the required people, budget etc. to be completed but in the real project environment, probably these activities will have to be completed with less resources and there are researchs to improve the methodology to provide concurrent resource distribution and activity planning (Hillier & Lieberman, 2000, p.512)

Also, PERT has another disadvantage in terms of assumptions. According to PERT there is a "statistical independence" among activities but a delay in an activity can affect the other ones, in fact. (Halphin & Senior, 2011)

Literature review has shown this, the oldest and best known methods in project scheduling management, such as Gannt Chart, CPM and PERT, are not perfect and there is a need for new approaches for more accurate and realistic techniques. CCPM seems to have potential to be a more comprehensive alternative for these methods with similar useful features. Also there are a number of success stories in implementation and recent academic researches about CCPM in the literature. Therefore, CCPM has been reviewed relatively deeper than the other methods and the empirical research part of the thesis mainly focuses to CCPM 's recognition in Turkey.

2.6. Theory of Constraints (TOC) and Critical Chain Project Management (CCPM)

The alternative project time management approach CCPM is derived from TOC. In other words, CCPM is the project management application of TOC , based on its theoratical roots. Thus TOC will be introduced first, in the next chapter of the study, although it is not only a project management consept.

2.6.1. Theory of Constraints (TOC)

The roots of TOC lies on development of a scheduling software by Goldratt and Cox, in 1979. TOC was introduced by Dr. Eliyahu Goldratt , an Israeli physicist , in his book '*The Goal*' in 1984, as a methodology for production planning and scheduling based on scientific thinking methods. In other words, he applied scientific methods to management. This book and the ideas in it has caught a wide interest.

After its recognition, various profession areas has started to implement the consepts of it , such as project management.

Although this book's main target was manufacturing professionals, after its recognition by a wide population, various academic researches have been conducted about TOC's consepts, philosophy and implementations. Thus this approach has been developed through the years. Watson et al. (2007, p.388) have seperated the development phases of TOC into eras , naming the eras with Goldratt's books' names and it's beneficial to understand the development of the TOC consepts through the years:

1. *The Optimized Production Technology Era* – the secret algorithm (1979-1984)
2. *The Goal Era* – articulating drum-buffer-rope scheduling (1984-1990)
3. *The Haystack Syndrome Era* – articulating the TOC measures (1990-1994)
4. *The It's Not Luck Era* – thinking processes applied to various topics (1994-1997)
5. *The Critical Chain Era* – TOC project management (1997-2004)

In order to understand an approach's essence, it is useful to comprehend the basic assumptions of it. There are three main assumptions that TOC philosophy relies on : (Schragenheim, 1999)

1. There is 'a goal' to accomplish for each corporation
2. A corporation is not limited with the combination of its parts
3. There are just a few constraints which affects the performance of a corporation

Resource management is an important management area in organizations as there is a strong relationship between resource management and cost/profit values. All

of the organizations (except for non-profit corporations) aim to earn money, as much as possible. According to the TOC management philosophy, every factor that has a negative effect on the organization's performance is a 'constraint'. In other words, everything that disrupts company to earn money, is a constraint. If the organizations can be able to keep under control these constraints and overcome them, a "continuous improvement" can be possible providing them more money (Şimşit et al. , 2014)

According to TOC, every organization is a 'system' . Systems consist of the parts that are connected to eachother. Activities in an organization is a 'chain' and the weakest link of the chain is the system's constraint and there is at least one weak link in every chain. (Süslüoğlu,2012) All efforts that are made in order to strengthen the overall system would be meaningless unless the weakest chain is fortified. Constraint management is about to handle this weak link in the chain.

There are five "focus steps" (5FS) defined in constraint management : (Cox & Spencer, 1998, p.57)

1. *Identify the system constraint* : The answer of the 'what limits the output' question is the first step of the constraint management. This is the identification of the weakest link. There must be at least one constraint within a system, otherwise there would be limitless growth and profit.
2. *Decide how to exploit the system constraint* : Here is the word 'exploit' means providing an advantage using the constaint's non-used capacity, implementing protective and improving applications on it.
3. *Subordinate all else to the constaint of the system* : This is the most difficult step for the managers to implement; considering the constraint as the priority.

4. *Elevate the system's constraint* : Implementing the solution which is decided to overtake the constraint.
5. *Go back to step 1*: As chain consists of independent parts, the changes that are implemented to constraint may affect other activities. Starting from the first step is needed for continous improvement. But it is important to "beware inertia" not to cause a new constraint. Constraints usually move from one point to another.

Roman and Conen (1992, cited in Şimşit et al. 2014) added two prior steps to these focusing steps , thus they turned to be 'seven focusing steps':

- Define the system's 'goal'
- Determine the global performance measures.

Theory of constraints uses 'thinking processes' to create solutions in terms of complex . These processes have been introduced in the Goldratt's book 'It's not Luck'. These processes are not only to be used in the solution of the bussiness problems, but also they can be used in an individual's daily life problems. Because they are not discipline spesific processes. Theory of constraints' aim is to handle 'the change' which is a main subject in the individuals' and corporations' everyday life, finding answers to these three fundamental questions: (McNeese, 2014)

1. What to change ? (identification of the constraint)
2. What to change to ? (What should we do with the constraint?)
3. How to cause the change ? (How do we implement the change ?)

There are five tools including four 'trees' and a 'cloud' that are used in thinking processes of TOC. These tools includes two kind of logic ; "cause-effect logic" and "necessary condition logic" (Şimşit et al. , 2014)

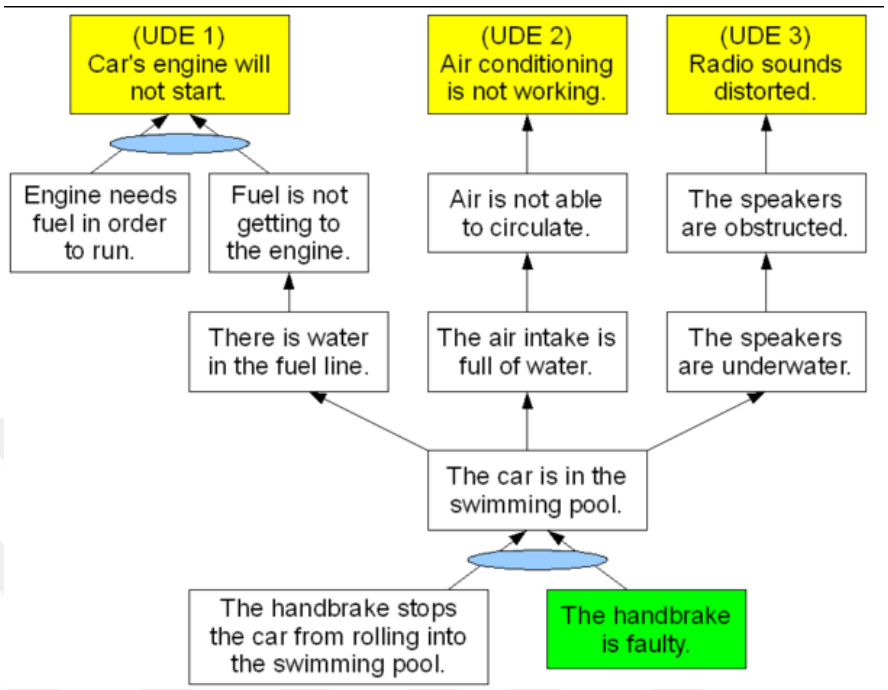
2.6.1.1. Current Reality Tree (CRT) :

This tool is an problem analysis tool which is based on cause-effect logic, to find ‘what to change’. Dettmer (2007, p.92-95) defines the CRT as a “logical structure” that is developed to make a decription of “reality” in the certain system and it shows the chain of cause-effect which has the highest probability in a stabile set of situations. It is hard for a person who is unfamiliar with the problem or a part of the problematic point to criticise or devolep the tree because it is required to acceptance of the reality. (Süslüoğlu, 2012) CRT is developed to enhance the comprehension of complex systems. It helps to find “root causes” of problems in the system. (Dettmer, 2007, p.147)

There is an example for CRT below. This tree shows the root cause and cause-effect relationships for three UDE’s (Undesirable Effects, problems) for a car which is in a swimming pool. The problems with the car’s underlying root cause is the faulty handbreak for this example.

Figure 12

Current Reality Tree



Note. UDE1, UDE2 and UDE3 represents problems. From (*https://en.wikipedia.org/wiki/Current_reality_tree_(Theory_of_constraints)#/media/File:CurrentRealityTree_Example.png*)

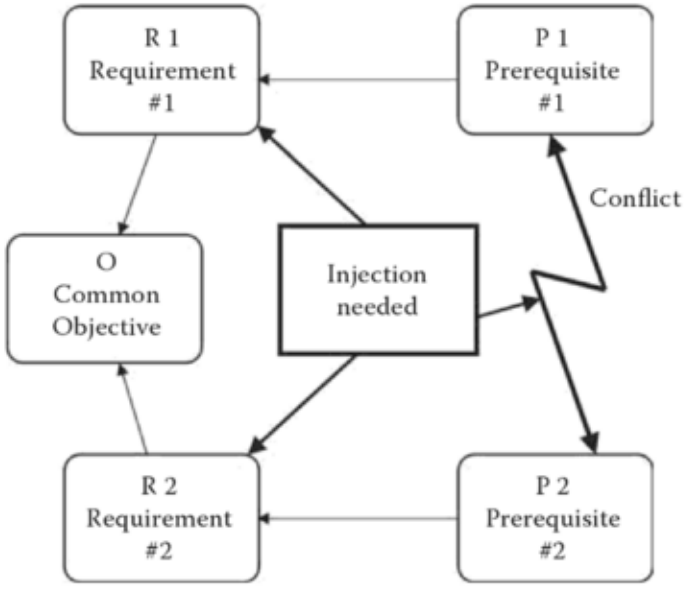
2.6.1.2. Evaporating Cloud (EC) :

Evaporating Cloud' is the "Conflict Resolution Diagram (CRD)" to solve the underlying conflicts which causes repetitive problems and EC assumes that the main problems (once they are identified) frequently have secret conflicts which are barriers to reach an overcoming resolution (Dettmer, 1997, p.239) EC tool is used to find the answer of one of the main thinking process questions :'what to change to?' EC assumes that both sides of the conflict must have the same goal with eachother, unless there will be no conflict and the aim of EC is turning the state from "me vs. you" to " me and you vs. problem" (Chambless, 2012) The main target is creating a "win-win" solution for conflicts.

In the EC example below , objective ‘O’ requires R1 and R2 to be achieved , P1 is the prerequisite of R1 and P2 is the prerequisite of R2. A conflict occurs between P1 and P2. There is need for an idea called “injection” here to solve the conflict. (Rantanen & Domb, 2010, p.214)

Figure 13

Evaporating Cloud



Note. Taken from *“Simplified TRIZ Second Edition, New Problem Solving Applications for Engineers and Manufacturing Professionals”,* by Kalevi Rantanen and Ellen Domb , 2010, p.214, Auerbach Publications, CRC Press, Taylor & Francis Group.

2.6.1.3. Future reality tree (FRT) :

McMullen (1998, p.61) defines FRT as “a picture of the game plan” and a diagram that illustrates “ideas” as “injections” with Goldratt’s term , which will be used in order to achieve “the desirable effects”. In other words, it is a diagram that helps to determine the future results of actions that are decided to implement for a current situation, establishing logical connections. It is a ‘what-if’ implementation.

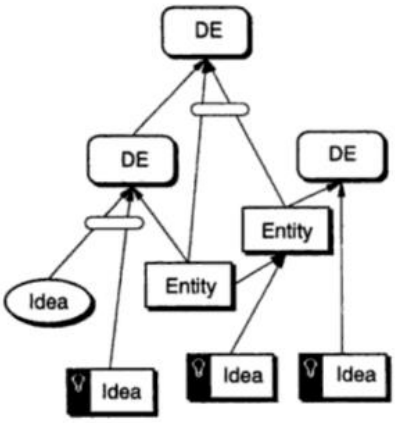
Dettmer (2007, p.25) asserts that FRT has two major advantages; it allows to "logically test" the intented actions before investing in and it gives a chance to prevent the current state from getting worse.

FRT helps to detect the possible future results of the organization's current decisions in the way of achieving target. It can be also used for personal purposes in daily life. Also it helps to find a solution to turn a UDE (undesirable effect) to a DE (desirable effect)

There is an example FRT diagram below. 'Ideas' represent 'injections' here to be established to reach a DE.

Figure 14

FRT Process and Diagram



Note. Taken from ***"****Introduction to The Theory of Constraints (TOC) Management System"* by Thomas B. Jr. McMullen, 1998, p.61-62, St. Lucie Press

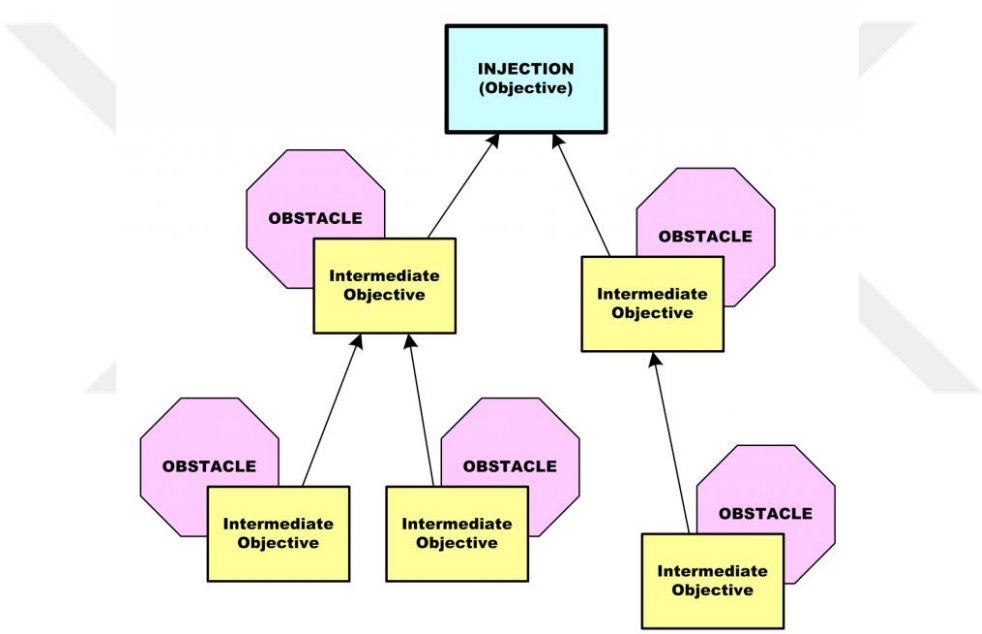
2.6.1.4. Prerequisite tree (PRT) :

PRT is based on necessary condition logic. In PRT, 'obstacles' which must be resolved to be able to establish ideas (injections) that defined in FRT are listed in detail (Kendall, 1998, p.324) In other words, PRT can be defined as a 'road-map' to

reach the targets and it considers potential “obstacles” and their possible solutions to reach the objectives. PRT consists of just three types of components : “an ultimate objective (in the top of the diagram), obstacles and intermediate objectives” and it reflects what is needed but missing in the current period of time. (Dettmer, 1998, p.173)

Figure 15

Prerequisite Tree



Note. Taken from Dettmer, H. William, *The Logical Thinking Process: A Systems Approach to Complex Problem Solving*, Milwaukee, WI: ASQ Quality Press, 2007, Ch.7.

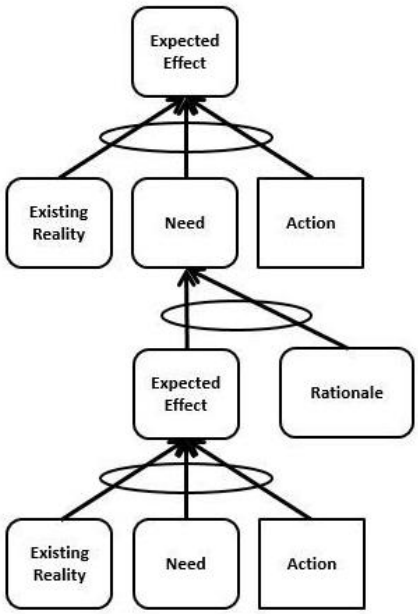
2.6.1.5. Transition tree (TT) *:*

Cause-effect logic is used in TT. It illustrates the steps of the change implementation, using “current reality” , “need” and “injection” elements, in sequence to achive an objective (Hohmann, 2015). It tries to find the answer for ‘how

to change' question. Dettmer (2007) asserts that, the transition tree is not preffered by the professionals and they add some extra details into the PRT and discard the TT implementation.

Figure 16

Transition Tree example



Note. Taken from C. Hohmann, *Thinking Processes Transition Tree*, 2015 *https://hohmannchris.wordpress.com/2015/07/13/thinking-processes-transition-tree/)*

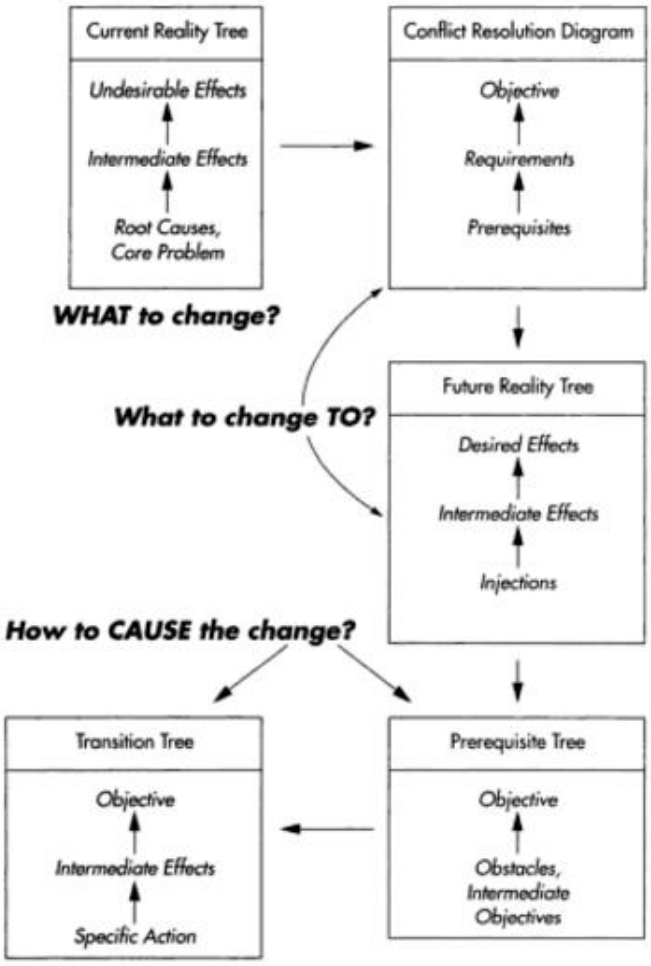
There is an interrelationship between these tools of TOC's thinking processes as the result of a tool can be used as a resource for another (Watson et al. , 2007, p.395) There is a diagram in **Figure 17** that shows this interrelationship between the tools and their usage for the main questions of TOC's thinking processes.

These thinking processes have been used to create solutions for various problems and for corporate improvement purposes by professionals and there are a number of academic research about this topic. But also there are contradictory ideas in the literature. Trietsch (2004) asserts that, TOC is not a completely correct method,

not including “balance” consept, not even a theory and has wrong parts but there is cases where it is useful. As one strong scheduling method alternative, CCPM was derived from TOC, it will continuously take part in the project management researches.

Figure 17

Interrelationship between the tools of TOC thinking process



Note. Taken from *“Goldratt’s Theory of Constraints: a System’s Approach to Continuous Improvement”* by H. William Dettmer , 1997 , p.28, ASQ Quality Press

2.6.2. Critical Chain Project Management (CCPM)

CCPM is a project management method which finds a place in the literature and CCPM was introduced in 1997, in Eliyahu Goldratt's novel 'Critical Chain'. It has been recognised as the application of TOC in project management field. Since 1950's project management has been a significant branch of the management science and operation research, also serious amount of projects was managed through the years in various sectors but methods has not been developed in the same balance.

CCPM was born as a result of looking for a new and more reliable method against disadvantages of the old techniques. Old techniques were developed to focus on activity durations but not to consider resource factor. But in the real project environment, resource availability and resource conflicts, because of multi-tasking, had always been serious problems. CCPM has brought a new sight to project scheduling considering resource availability. As 'resource' is 'human' in software development projects, ignoring the impact of human behavior on the progress of planning causes plans made on paper to not yield accurate results in the real project management environment. So, this was a shortcoming for traditional techniques such as CPM. Furthermore, the old methods' procedures proved inadequate for multi-project environments. Such shortcomings of old methods supported CCPM to come to the scene.

Treitsch (2004), described the main differences between CPM and CCPM as listed below ;

1. CCPM uses resource constraints instead of resource leveling
2. CCPM eliminates due dates to manage activities
3. CCPM uses buffers (project and feeding buffers)

4. CCPM cares about avoiding multitasking

In order to implement TOC principles into project management environment, the rule is keeping 'the goal' in mind. The goal of a project, in terms of generally accepted criterias, can be defined as completing the project within scope boundaries, budget and time.

There are implementation steps of TOC to the project environments below. In other words, these are the implementation principles of CCPM and this is and continuous cycle :

1. Identify the Critical Chain : In the way of achieving the goal, the first step is identifying the system's constraint and according to CCPM, the project schedule's constraint is the '*critical chain'*. According to Leach (2014, p.98) , critical chain is "the longest path through the network after resource leveling". Resource leveling can be described as implementing decisions to the activities' start and finish times considering resource constraints. This approach brings a strategical logic to the project time management activities. If there are no resource constraints in the project, critical chain can be identified same as critical path but mainly it is different from critical path as considering resource precedence and not changing as critical path changes through the project duration (Leach, 1997, p.4). Total project completion time depends on the resources that are responsible with the activities through the critical chain. According to this approach, resource availability is an important factor to be considered that effects the project duration.

In order to identify the critical chain, these sub-steps below must be implemented, (Leach, 2004)

- Arrange the as-late-as-possible network of activities executing backward pass computation. The activities should define the completion time estimation and required primary resources.
- If there are no resource conflicts in the project, jump directly to the 6th. step
- Determine which conflict to be resolved first. The conflict which is closest to the end point of the project or the hardest conflict must be selected. If there are more than one conflict that have same features, the one which is closest to the end must be resolved.
- Resolve resource conflict "re-sequencing" the activity earlier.
- Go to the end of the network and implement 4th step for the second conflict. While resolving the conflicts, prevent causing another conflict emerge on the previous resource. Resolve all of the conflicts.
- Determine the critical chain identifying the longest chain through the network.

2. Exploit the Critical Chain : The Critical chain is described as as the longest chain of dependent steps forming the constraint. Activities can also include dependencies because they use the same resource (Goldratt, 1997). After identifying the critical chain, the second step must be to decide 'how to exploit the critical chain'. Different ways can be found for this. While checking the network if some activities seem to shorten the project completion time in case of re-sequencing, they must be re-sequenced.

Two solution steps that CCPM brings out are ; Valikoniene (2014, p.45)

- Reducing task completion time

- Adding the “project buffer” in the of the project (this term will be defined in the further part of the study)

3. Subordinate other tasks, paths and resources to the critical chain : Considering all other activities in the process, it is checked whether they are compatible with the needs of the constraint and aligned with it.
4. Elevate the consantraint : Here, ‘elevate’ means taking action to support critical chain, adding extra resources or changing resources, activity lineup, tools etc. where the problem occurs (Valikoniene (2014, p.45)
5. Repeat

Figure 18

TOC and CCPM Steps Comparison

	TOC	CCPM	
STEPS	1. Identify the system’s constraint(s)	1. Identify critical chain	1.1. Develop the baseline schedule 1.2. Find the critical chain
	2. Decide how to exploit the system’s constraint(s)	2. Decide how to exploit critical chain	2.1. Reduce activity duration 2.2. Insert project buffer
	3. Subordinate everything else to the above decision	3. Subordinate other tasks, paths and resources to the critical chain	3.1. Insert feeding buffer 3.2. Reschedule after inserting feeding buffers 3.3. Insert resource buffers
	4. Elevate the system’s constraint(s)	4. Elevate the critical chain	4.1. Evaluate the schedule 4.2. Elevate the critical chain
	5. If, in previous steps, a constraint has been broken, go back to step 1, and do not allow inertia to cause a system’s constraint.	5. If, in previous steps, a constraint has been broken, go back to step 1.2.	

Note. Adapted from “*Resource Buffers in Critical Chain Project Management*” by Valikoniene, L. (2014), p.46, [Doctoral dissertation, University of Manchester]https://www.escholar.manchester.ac.uk/api/datastream?datastreamId=FULL-TEXT.PDF&publicationPid=uk-ac-man-scw:261510

2.6.2.1. Uncertainty

In project planning, task completion time estimations play a fatal role. Because, all the work to be done within the scope of the project is divided into task units and the total project completion time is tried to be reached by calculating how long each of these tasks will take. However, while these plans are being made, there are some uncertainties due to the nature of the project environment. Task completion times are usually estimated by taking into account the time that similar tasks were completed in previous projects (ie memory.) In addition, the risks identified for the project are also taken into account. Often, the resource who will complete the task will indicate how long it will take to complete the task and submit it to be added to the project plan.

CCPM relies on the assumption that when calculating task completion times by resource managers, they tend to set an excessive amount of time to avoid problems due to late completion. Also, people think that if a task is completed earlier, in the next project this completion time would be considered so they make a cautious estimation (overestimation). So we can say, CCPM assumes that every task duration in the project plan has a hidden safety time added inside.

Tasks are estimated cutting their initally estimated completion time by %50 according to CCPM principles to exploit the critical chain (Goldratt, 1997)

Figure 19

Probability of task duration

Note. Taken from "*Improving focus and predictability with critical chain project management"* by J. Cooper, 2013, Copyright by PA: Project Management Institute

The figure above says that, if nothing unexpected occurs the task's duration probably will be 2 days but it will be completed in 5 days (optimistic) if some there is some uncertainty within the plan and it will only last 12 days (pesimistic) if a disaster occurs. CCPM uses %50 confidence line (optimistic).

2.6.2.2. Human Behaviour

As indicated before, the main component of a project is 'human' and human behavious can directly effect an activity duration. At the end of the day, the entire project plan may be adversely affected and even the project may fail due to these negative effects.

CCPM addresses some of the fundamental problems associated with human behavior.

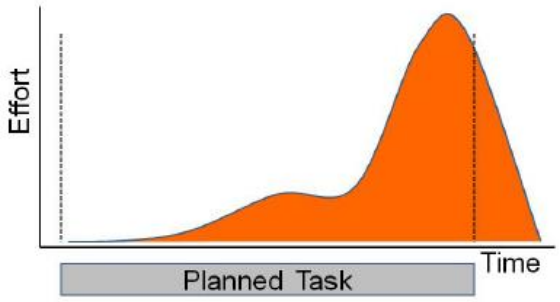
2.6.2.2.1 Student's Syndrome

During the school years, students often do nothing while they still have plenty of time to study for a test or finish an assignment and they try to complete all the work on the last night . This is actually caused by human psychology. Goldratt (1997) likens the resources assigned to the projects to students who leave their homework until the last night, as reasources postpone the tasks they need to complete until the last possible time and do the things that are of highest priority to them first. Mostly, multi-tasking working environment causes this situation as there are always something else to complete about other projects so eventually the resources filter the tasks in their very own way. This is why CCPM tries to discourage multi-tasking in projects.

In the Figure 20 below, it can be said that, minumum effort has been given in the beginning and task is completed with a maximum effort in the last period of planned time. This is a disadvantage because if something wrong happens during the execution of the tast, there will be no more security time to waste (as whole security time had already wasted) and the delay will occure in the project planning.

Figure 20

Student Syndrome



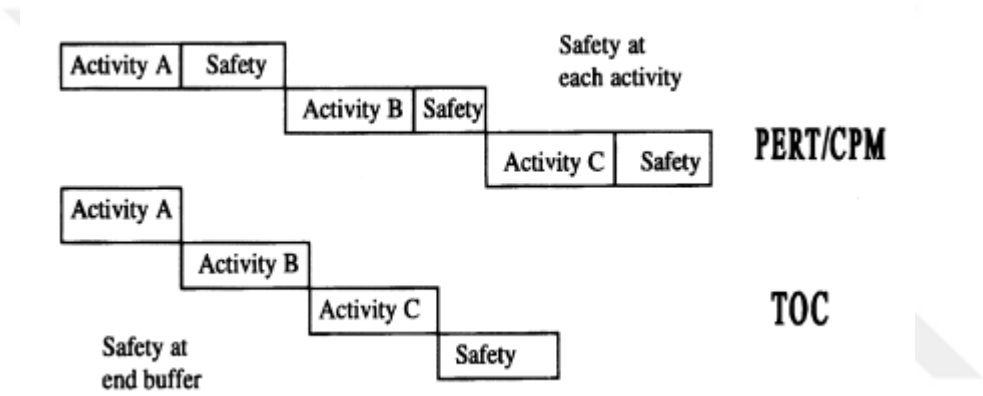
Note. Adapted from "*Improving focus and predictability with critical chain project management"* by J. Cooper, 2013, Copyright by PA: Project Management Institute

CCPM suggests to remove safety time which was added to the activities so resources don't feel comfortable thinking they have more time to complete the task. In old methods like CPM, the safety time is added after activities but in CCPM, safety buffer is removed from activities and added to the critical chain of activities.

It can be seen in the figure below differences in the safety time additions for CPM/PERT and CCPM :

Figure 21

Safety time comparison between PERT/CPM and TOC



Note. Adapted from "*Critical Chain: The Theory of Constraints Applied to Project Management*" by Graham K. Rand, 2000, s.176 , International Journal of Project Management, Vol: 18, https://doi.org/10.1016/S0263-7863(99)00019-8.

2.6.2.2.2 Parkinson's Law

There is another human behaviour that CCPM takes into account called 'Parkinson's Law'. Parkinson and Osborn (1957) defined the law as "work expands so as to fill the time available for its completion" When the people have more time than actually needed, they tend to use it unnecessarily. For example they do some extra amendments in the task that is not in the scope or maybe they do most of the work but do not finish and deliver it until its deadline or make some extra tests and

the next task doesn't start in such situation. This means, the saved time in an activity can't be used for whole project's early or on-time completion goal.

There is a case study which Hohmann (2016) mentions about a company that suffers from Parkinson's Law in terms of on-time deliveries, tried CCPM and some good results were taken despite there was a badly multi-tasking environment in the company that interrupts resources to focus on their tasks.

2.6.2.2.3 Multitasking

Multitasking means, a resource takes more than one project's tasks at a time. This situation creates negative effects for a project plan like Student Syndrome and Parkinson's Law. This situation is frequently experienced in corporations that want to complete all their projects with a small number of resources, and even the normal way of doing business has become multi-tasking. Some managers may even be proud that their team is handling multiple projects at once.

There are some negative effects of multitasking are listed below (Leach, 2014):

- *Each task takes longer*: When a resource goes to complete another task for an amount of time, this will cause to complete the task later than expected as long as multi-tasking time.
- *The waste of time and attention for transfers among tasks:* Leach (2014) cites an experiment that concluded that there was more time wasted, depending on the number of times it was switched between multiple tasks that required different types of cognitive attention (Ghaffari, 2016) It seems normal to take some time to regain the same speed in completing the work that was

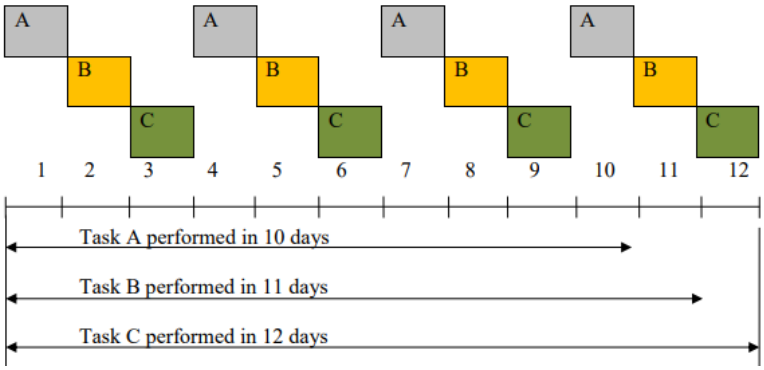
interrupted by providing the same concentration when returning after a break while doing a job.

- *Results in less throughput:* Leach (2014) said that multitasking people seems like busy and so they think they complete more; but, because of variable effects in multitasking those resources complete less task in a certain period of time comparing to working on tasks sequentially.
- *Quality of work plummets:* According to Leach (2014), resources tend to make more mistakes when multitasking. When people are interrupted while doing one job, they may make mistakes due to lack of concentration.
- *Higher levels of anxiety:* Trying to do more than one job at the same time is a situation that causes the stress of the source to increase.
- *Learning becomes more difficult :* Since an end-to-end experience cannot be provided due to the deterioration of concentration while switching between a job and another job, it may be expected that learning becomes difficult.
- *Negative effect in the organisational level*

There is a comparison in two figures below , showing negative effects of multitasking on resources' performances. In this comparison, task performances with and without multi-tasking can be seen and according to this comparison, project will be completed at the same time but the two of three resources will have to work more in multi-tasking version ;

Figure 22

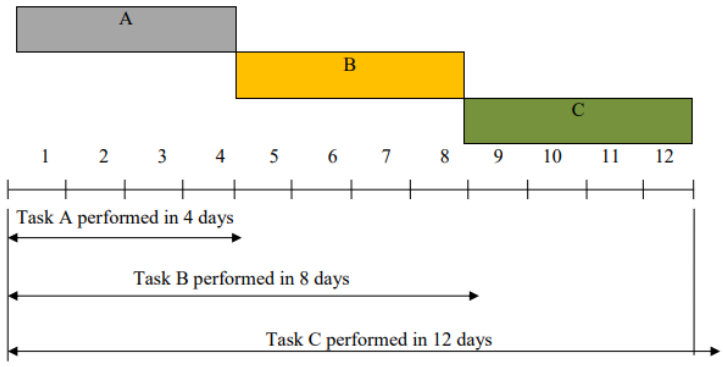
Multi-tasking performance



Note. Adapted from "*Resource Buffers in Critical Chain Project Management*" by L. Valikoniene, 2014, p.53, [Doctoral dissertation, University of Manchester] https://www.escholar.manchester.ac.uk/api/datastream?datastreamId=FULL-TEXT.PDF&publicationPid=uk-ac-man-scw:261510

Figure 23

Performance without multi-tasking



Note. Adapted from "*Resource Buffers in Critical Chain Project Management*" by L. Valikoniene, 2014, p.53, [Doctoral dissertation, University of Manchester] https://www.escholar.manchester.ac.uk/api/datastream?datastreamId=FULL-TEXT.PDF&publicationPid=uk-ac-man-scw:261510

2.6.2.3. Buffers

Time buffers can be explained as the extra time added to the initial timing estimate in order to prevent the project delivery from being delayed as a result of unexpected situations that may arise during the completion of the tasks. Buffer is part of risk management consept indeed. In traditional methods like CPM, ‘safety time’ is added to the task durations. But in CCPM approach, buffers are aggregated and added to the project completion time. Thus, the aforementioned delays caused by human psychology are tried to be avoided.

Buffers are added taking into account uncertainties in the calculation of activity times (Tukel et al, 2005) and in CCPM, buffers are used to prevent delays in the critical chain.

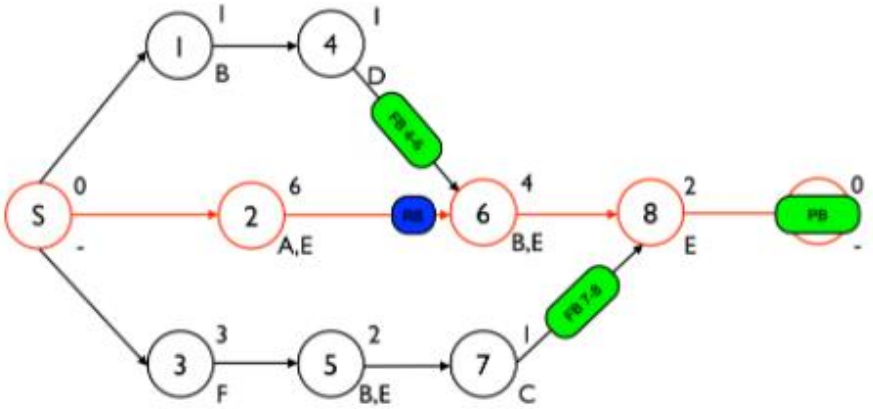
There are three types of “buffer” in CCPM approach : Project buffer, feeding buffer, resource buffer.

- Project buffer ; Predetermined extra times for each task are subtracted from the task duration and added to the end of the project. In other words, the additional time that will likely be consumed for each task with the addition of the project buffer is used to protect the entire project from possible delays.
- Feeding buffers are added to the end of non-critical paths to prevent the critical chain from delaying non-critical activities. (Valikoniene, 2014, p.56) This type of buffer added before the first task in the critical chain in order to prevent delays in non-critical tasks from causing delays in the critical chain. Feeding buffer size is half of the critical chain duration.
- Resource buffer, carries “buffer” in its name but it indicates no extra time, just a warning alert for resources that remind it does not indicate extra time, it is

simply a warning alert to remind resources that a critical chain mission is approaching like a “wake-up-call” .. There are no explained ways to calculate resource buffer size.

Figure 24

Buffers in CCPM



Note. Network diagram shows two feeding buffers , one resource buffer and project buffer additions to the project. Tasks 2-6-8 forming the critical chain. Adapted from *Sizing CC/BM Buffers : The cut and paste method, 2012,* http://www.pmknowledgecenter.com/dynamic_scheduling/risk/sizing-ccbm-buffers-cut-and-paste-method

When it comes to calculate buffer size , Goldratt (1997) explained the most simple buffer sizing method in his book Critical Chain , “cut and paste” method. According to this method, %50 of the critical chain’s duration added to the project as project buffer and this safety time is eliminated from single tasks. The idea behind this implementation aims to use this extra time for whole project and prevent resources to consume this time for each task.

This calculation is easy but it has some shortcomings in it. If there is a task that is too long, it can also cause the buffer to be unnecessarily long. In addition, in

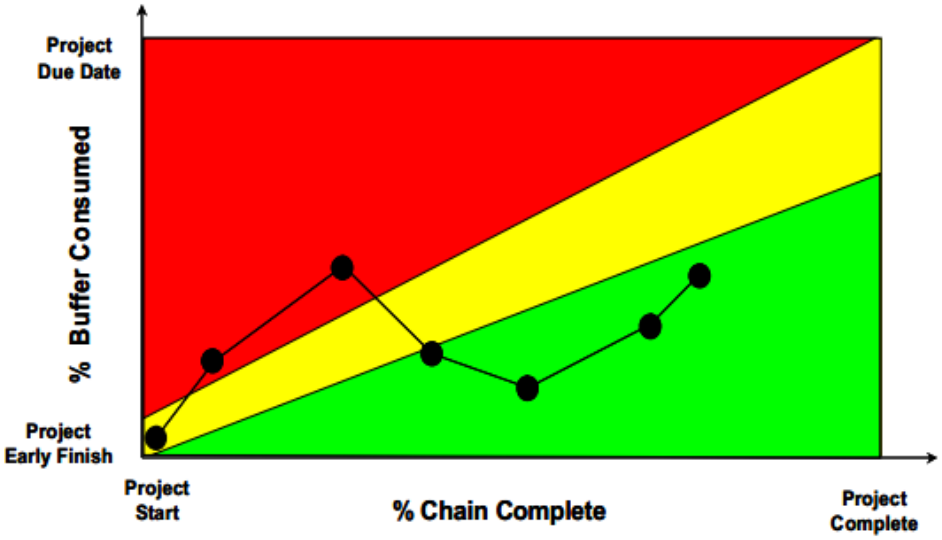
this calculation, the diversity between the tasks seems to be ignored. (Kannan & Chitra, 2017)

In the CCPM approach, great importance is attached to monitoring activities. The general progress is followed by measuring how much of the buffers have been spent, the occurrence of cost-increasing risks, and the overall completion percentage of the project. Also, in the CCPM approach, the monitoring process is simpler compared to the old methods, since the overall viewing of the project is done through buffers. In methods such as CPM, it is necessary to monitor the completion times of the tasks in order to predict possible delays in the project.

A 'fever chart' can be used to decide whether any actions needed or not, controlling the state of buffer consumption ratio and critical chain's completion ratio

Figure 25

Fever Chart



Note. Adapted from "The Critical Chain", Labrini, 2018, http://apppm.man.dtu.dk/index.php/The_Critical_Chain_Method

In fever chart, green areas need no action, yellow zone means problem must be defined and be ready for action and red zone means emergency, action needed.

2.6.2.4. CCPM Implementation Success and Advantages

As mentioned early parts of the study, CCPM has significant pros. compared to the old methods like CPM/PERT as summarised below;

- CCPM focuses human related problems in project scheduling like Student's Syndrom, Parkinson's Law
- Provides easier monitoring
- Considers critic resources and tasks
- Provides shorter project duration estimations

Some of the benefits of CCPM that Leach (2014) asserts are below :

- Increased project success , completing it in less time , in accurate scope and with less cost
- Decreased project completion time (minimum %25 less completion time for single projects and shorter duration for multi-project environments)
- Decreased conflicts which multi-tasking causes
- Increased ROI

In a research report in the literature, Millhiser and Szmerekovsky (2011) listed 53 company that implemented CCPM and reported improvements in a table. Among these companies, there are big and serious corporations like Japanese Ministry, US Army, US Air Force , Bosch Security Systems etc. Also, Dilmaghani (2008) describes CCPM , despite its pitfalls, "simple but effective" regarding CCPM implementation in Bosch Security Systems Eindhoven. Lechler et al. (2005) mentioned some case studies with improvement results of CCPM application

including increased on-time delivery, reduced overtime. Also, Realization Technology company publishes videos consisting of success stories of diffrent customers consists of striking improvements in terms of project completion time.

Izmailov et al. (2016) puts CCPM in a valuable position in their study and express their opinion with assertive sentences ; "*may be the most effective approach to the projects planning in the last 30 years. In dozens of projects it already proved that it helps to protect project completion time from various unavoidable risks, that occur in every project."*

If we take into account the literature research, the supporters of the CCPM method do not seem to be in the minority at all. In a study by Repp (2012), some CCPM implementation factors are extracted from the literature review. These advantages of CCPM implementation also used as a question in the survey and its results are given in the next chapter ;

- Ensures the completion of projects in less time
- Increases the rate of delivering projects on time
- Stress in the work environment is reducted
- Increases the completion chance of projects
- Increases the project efficiency
- Minimizes the changes of project scope
- Minimizes the increase of Project costs
- Reduces the need of Multi-tasking for resources
- Provides better prioritization of sub-tasks in the project
- Gives a chance for trying a new successful method that is used by different companies
- Provides financial benefits to the company

2.6.2.5. Shortcomings of CCPM

In literature, there are lots of success stories about CCPM and this raises the question of why this method, which is claimed to be very useful, finds little application area. It is nearly not possible to come across a successful CCPM story in the literature in our country. Beside this, The number of researchers who discuss about CCPM's negative aspects is also not less.

According to Dilmaghani (2008), "CCPM *prosedures are intensive and time consuming"* . There are software products in the market to make duration estimations automatically as it is difficult to calculate task durations and buffers.

Researches Lechler et al. (2005) and Millhiser and Szmerekovsky (2011) claims that, there are a number of failed CCPM implemented projects but they were not reported to the public. So, projects with negative results may have been overshadowed by the fact that those with positive effects are more likely to be shared.

Another hesitation point for implementation could be 'resistance'. In some resources, it has been stated that organizational resistance to CCPM procedures causes pitfall for CCPM's prevalance (Dilmaghani, 2008).

Focusing on the critical chain, Raz et al. (2003) see this feature of CCPM as a handicap, mentioning the possibility that if the tasks in the non-critical path are put in the background, these tasks are important or will result in penalties in case of delay. In the same research paper, they summarized their findings as followed: "*Our conclusion is that although CCPM has a number of valuable concepts, it does not provide a complete solution to the needs of project management. Consequently, organizations should be very careful when considering the adoption of CCPM to the exclusion of conventional project management techniques and methods."*

Over the years, as the research and discussions on the subject increase and examined from different perspectives, different negative aspects of CCPM method seem to emerge in the literature.

3. RESEARCH DESIGN AND METHODOLOGY

The survey method is selected for the research, as another field method such as case study or action research couldn't be possible. The definition of a survey according to Pinsonneault and Kraemer (1993) is a "means for gathering information about the characteristics, actions or opinions of a large group of people" . Michael Ishman (1998) mentions that survey method is widely used in Management Information Systems area. Attewell and Rule (1991) mentions that "the survey method is strong in areas where field methods are weak".

In this part of the study, the data that gathered through the survey research aims were examined in the scope of descriptive and statistical analysis. Surveey.com platform is used to conduct survey. Link is sent to the participants via e-mail.

Main goal of the examination were the exploring the knowledge and usage of the CCPM method among project management professionals and the potential of the method on project management.

An online questionaire was sent to more than 250 project management professionals from different companies and sectors within this research. Response rate was less than %40 among this professionals. But, some of them sent the survey link to their collagues and friends, so 136 responses were returned in the end. As it is difficult for people to spare time for such studies due to their hard work, higher number of answers could not be reached. The difficulties in applying a survey as a research method constitute the limitation of this research. On the other hand, it should be kept in mind that some of the answers given to the survey questions are based on people's own comments.

4. ANALYSIS RESULTS

In this section, it has been tried to find answers to the research questions stated at the beginning of the study through the survey results and provide a deeper understanding about project management implementation practices in our country.

The research questions are defined as below ;

1. Is CCPM approach ***known in Turkey*** ?
2. Is CCPM approach ***applied in Turkey*** ?
3. Are there any differentiations between CCPM experienced participants and non-experienced participants in terms of methodology benefits consideration?

In this part, the descriptive analysis of the research data were examined with the frequencies and percentages. In the Table 3 below the distribution of the general project management variables were presented. According to the findings regarding the Project Management Experience of the sample, 11 (%8) of the participants have no project management experience, 8 (%6) of the participants have an experience of less than a year, 38 (%28) of the participants have 1-3 years of experience, 42 (%31) of the participants have 4-7 years of experience, 7 (%5) of the participants have 8-10 years of experience and lastly, 30 (%22) of the participants have experience of more than 10 years. This means, %58 of the sample have more than 4 years project management experience and the high number of experienced participants is a positive factor in terms of the reliability of the answers.

The distribution of the findings of the variable in which the connections of the participants with the project management were examined were as follows; 52 (%38)

participants are project manager, 20 (%15) participants developer, 23 (%18) participants business analyst, 24 (%18) of the participants are test officer, 6 (%4) of the participants are project management officer, 5 (%4) of the participants are user or project owner, 4 (%3) of the participants are project sponsor and lastly 2 (%1) of the participants are working unrelated the project management task. In a project team, all members know the method used in the project but since project managers follow the general process, they can have a better grasp of the details of the methods, so the fact that 38% of the sample is project manager can be considered as a factor that increases the accuracy of the answers we receive.

Finally, according to the distribution of the variable in which it is questioned whether the employees work in a project management-oriented organization; 72 (%53) of the participants have worked in an organization that project management oriented, and 64 (%47) of the participants have not worked in a project management oriented organization.

Table 3

Distribution of the General Project Management Variables

		Frequency	*Percent*
Project	No Experience	11	8
Management	Less than a year	8	6
Experience	1-3 years	38	28
	4-7 years	42	31
	8-10 years	7	5
	More than 10 years	30	22

Project	Project manager	52	38
Management	Developer	20	15
Connection	Business analyst	23	17
	Test officer	24	18
	Project management officer	6	4
	User/Product owner	5	4
	Project sponsor	4	3
	Unrelated task	2	1
Project			
Management	Yes	72	53
Office Experience	No	64	47
Total		136	100

In the Table 4 below, the project management certificates of the sample were presented. According to the finding, while the majority of the sample have no project management certificate (N = 97; %70), PMP is the most common certificate.

Table 4

Project Management Certificates

		Frequency	*Percent*
Project Management	PMP	31	23
Certificates	CAPM	4	3
	PRINCE2	3	2
	Others	14	10
	No Certificate	97	70

When the participants project involvement were investigated ,45 (%33) participants have involved 0-5 projects, 19 (%14) participants involved 6-10 projects, 29 (%21) participants involved 11-20 projects and lastly, 43 (%32) participants involved more than 20 projects. On the other hand when the project involvement of the participants were examined through the methods usage in the projects 7 (%5) participants stated methods never used in the projects, 25 (%18) participants stated that the "Method used in few projects", 23 (%17) participants stated that the "method was used in about half of the projects", 47 (%35) of the participants stated that the "methods was used in the majority of the projects" and finally, 34 (%25) of the participants stated that the "methods used in all projects" Here, it is seen that the majority of the sample used certain methods in the project management activities carried out in the companies they work for. Therefore, we can consider that there is a sample with a high probability of answering questions about the methods used.

Moreover distribution of the decider of the methods usage obtained as follows; 34 (%25) of the participants stated the project manager is the decider of the usage of the methods, 34 (%25) of the participants stated that the methods usage actions have taken according to the Joint views of the project team, 31 (%23) of the participants stated that the company management is the decider, 36 (%26) of the participants stated that the "Methods that are already embedded in the company culture are used, no choice is made" and lastly 1 (%1) participants stated that the project owner is the decider. This distribution tells us that there is no single answer to who determines the preferred method in project management, it can vary from organization to organization.

Table 5

Project Involvement and Methods Usage

		Frequency	Percent
Project Quantity	0-5	45	33
	6-10*	19	14
	11-20*	29	21
	more than 20	43	32
Method Usage Frequency	never used	7	5
	Method used in few projects	25	18
	The method was used in about half of the projects	23	17
	The method was used in the majority of the projects	47	35
	Method used in all projects	34	25
Decider of Method Usage	project manager	34	25
	Joint views of the project team	34	25
	Company management	31	23
	Methods that are already embedded in the company culture are used, no choice is made	36	26
	project owner	1	1

Table 6 presented below shows the mean values of the method selection determinants. According to the findings size of the project has the highest score (4,2±1,1) among the other determinants, while the other determinants have a similar mean scores. According to this finding it could be stated that the context of method selection size of the project has the highest importance.

Table 6

Mean values of the method selection determinats

	X±Std	Min-Max
Size of the project	4,2±1,1	1-5
Frequency of meeting w team	3,5±1,1	1-5
Client involvement	3,4±1,2	1-5
Clarity of needs	3,6±1,2	1-5
Constraints of the project	3,6±1,2	1-5
Risks	3,8±1,2	1-5
Complexity level	3,6±1,2	1-5
Tools used	3,1±1,1	1-5
Compliance with corporate culture	3,4±1,3	1-5

In the Table 7, distribution of the methods used were presented. According to the findings most importantly the CCPM has been used by 12 (%8) participants, while the Waterfall (N=81) and Agile Approach Derivatives (N=85) were the most commonly used methods. As an answer to one of the research questions of the study, whether CCPM is applied or not, we see that it can find a very narrow application area.

Table 7

Distribution of the Methods Used

		Frequency	Percent
Waterfall	Yes	81	60
	No	55	40
Agile Approach Derivatives	Yes	85	62
	No	51	38
PRINCE2	Yes	10	7
	No	126	93
PMI PMBOK	Yes	30	22
	No	106	78
Six Sigma	Yes	40	30
	No	96	70
CCPM	Yes	12	8
	No	124	92
CPM	Yes	39	29
	No	97	71
PERT	Yes	34	25
	No	102	75
GANTT Chart	Yes	56	41
	No	80	59
Instition Methods	Yes	68	50
	No	68	50
Others	Yes	42	30
	No	94	70

In the Table 8 the general findings about the CCPM presented. According to findings related the CCPM's consideration as option in the organization 7 (%5) participants stated that the CCPM considered as an option in the projects, 56 (%41)

participants stated that the CCPM did not considered as an option and lastly 73 (%54) participants don't know about the CCPM's consideration in the organization. The reason for asking this question was to interpret that even if CCPM is not being implemented, there may be a chance to be applied prospectively if there is a known and considered alternative. However, when we look at the ratios, it is understood that it is not implemented and is not included in the agenda as an alternative in the part that constitutes the majority.

When the participants knowledge about the CCPM were investigated only 3 (%2) participant have stated that the "I'm pretty good at all the details" and 43 (%32) of the participants stated that the "I have no knowledge". Also, according to the participants CCPM used Project involvement 7 (%5) participants have involved a Project that used CCPM and 129 (%95) of the participants not involved a Project that uses CCPM. From this, it is concluded that the awareness level of CCPM, which is another research question, is also quite low.

Table 8

Findings About the CCPM in General

		Frequency	*Percentage*
CCPM as Option	Yes	7	5
	No	56	41
	I dont know	73	54
CCPM Knowledge	I have no knowledge	43	32
	I have very little knowledge	42	31
	I know the fundamentals	28	21
	I know enough to apply	20	15
	I'm pretty good at all the details.	3	2
CCPM Involvement	yes	7	5
	no	129	95

By asking the participants of the survey, the importance of CCPM advantage factors (that was mentioned in the related part before) in terms of the expected benefit from a project management method, it was aimed to investigate which of the benefits of CCPM revealed in the literature are considered by project management professionals and therefore can be benefited if CCPM finds a more widespread application.

In the Table 9 below the mean values of each item that obtained from expected benefits of the project methodology were presented. According to the findings the "Providing financial benefits to the company" item has the highest score (4,79±0,4), followed by the items of "Increasing the rate of delivering projects on time" (4,72±0,4) and "increasing the completion chance of projects" (4,72±0,5). In this context it could be stated the participants are considering the financial advantages, deliver rate and completion chance more important than the other factors.

Table 9

Mean values of the expected benefits of the project management methodology

	X±Std	Min-Max
Ensure the completion of projects in less time	4,55±0,6	3-5
Increasing the rate of delivering projects on time	4,72±0,4	4-5
The reduction of stress in the work environment	3,25±1,3	1-5
increasing the completion chance of projects	4,72±0,5	3-5
Increasing the project efficiency	4,58±0,5	3-5
Minimizing the changes of project scope	3,71±1,0	1-5

Minimizing the increase of Project costs	4,50±0,6	3-5
Reducing the need of Multi-tasking for resources	4,05±0,9	2-5
Providing better prioritization of sub-tasks in the project	4,61±0,6	3-5
Trying a new successful method that is used by different companies	3,37±1,2	1-5
Providing financial benefits to the company	4,79±0,4	3-5

On the other hand, using Independent Sample's T test, it was aimed to understand if there is a differentiation between participants who are experienced in CCPM and non-experienced. In the Table 10 below the results of the Independent Sample's T test that conducted between the CCPM Usage and Expected Methodology Benefits were presented. According to the findings there is statistically significant mean differentiation between the "The reduction of stress in the work environment", "increasing the completion chance of projects", "Minimizing the increase of Project costs" and "Providing financial benefits to the company" and CCPM Usage

When these differantiations were examined it could be stated that in all meaningful differences the participants who use CCPM in their organization have higher average scores than other participants.

Table 10

Independent Sample's T test between CCPM Usage and Expected Methodology Benefits

		X	*Std*	*t*	*Sig*
Ensure the completion of projects in less time	Yes	4,83	0,39	1,482	0,141
	No	4,53	0,69		
Increasing the rate of delivering projects on time	Yes	4,83	0,39	0,855	0,394
	No	4,72	0,45		
The reduction of stress in the work environment	Yes	3,83	1,11	**1,605**	**0,011**
	No	3,19	1,34		
increasing the completion chance of projects	Yes	4,83	0,39	**0,847**	**0,039**
	No	4,50	0,49		
Increasing the project efficiency	Yes	4,58	0,67	0,016	0,987
	No	4,58	0,54		
Minimizing the changes of project scope	Yes	3,50	1,38	-0,748	0,456
	No	3,73	1,00		
Minimizing the increase of Project costs	Yes	4,75	0,45	**1,371**	**0,017**
	No	4,48	0,66		
Reducing the need of Multi-tasking for resources	Yes	4,42	0,79	1,341	0,183
	No	4,02	0,98		
Providing better prioritization of sub-tasks in the project	Yes	4,58	0,79	-0,148	0,882
	No	4,61	0,65		
Trying a new successful method that is used by different companies	Yes	2,83	1,03	-1,642	0,103
	No	3,43	1,21		
Providing financial benefits to the company	Yes	4,92	0,29	**1,009**	**0,031**
	No	4,58	0,45		

5. DISCUSSION

When we look at the survey results, the awareness and application level of CCPM in our country seems quite low. In this case, if it has the potential to add value that can make a difference for companies as mentioned in many different sources, this potential will not be utilized.

Considering the position of the CCPM method in the literature, although it has controversial points, it seems that the benefits can be experienced if there is no resistance in the teams and if monitoring and taking action when necessary are carried out regularly. But sufficient research about CCPM's long-term effects in corporations couldn't find during the literature review. So, it seems to be early to say it must be the only methodology for a company in project management. But, it is seen as a promising method as understood from the reviewed publications and case studies.

On the other hand, according to the survey results, the total of those who state that they know all the details and know enough to apply is 23, but on the other hand, the number of people who apply it seems to be 7. This makes us think that even in an environment where the method is known, it cannot find an application area, so the only reason for not being applied is not being known.

Also, the Independent Samples T-test showed us that there is a difference in the expected benefits from the project between those who practice CCPM and those who do not, and that those who have implemented CCPM are more sensitive to the benefits of reducing project costs and delivering projects on time.

It is recommended that further studies should be conducted to examine the potential benefits of CCPM more scientifically and systematically and to increase its awareness and application prevalence in order to provide these benefits. Also, wider

groups may be give different results as relatively low sample number (136) may not give result that can be generalized.

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APPENDIX

Survey Questions

1. Proje yönetimine ilişkin deneyim süreniz nedir?

(Sadece bir seçeneği işaretleyiniz.)

- Proje deneyimim yok
- 1 yıldan az
- 1-3 yıl
- 4-7 yıl
- 8-10 yıl
- 10 yıldan fazla

2. Proje yönetim faaliyetleri ile bağlantınız nedir?

Kendiniz için en yakın olanı seçiniz

- (Sadece bir seçeneği işaretleyiniz.)
- Proje yöneticisi
- Yazılımcı
- İş analisti
- Test yetkilisi
- Proje yönetim ofisi yetkilisi
- Uygulama kullanıcısı/ürün sahibi
- Proje sponsoru
- Proje yönetimi ile bağlantısı olmayan bir görev

3. Bugüne kadar hiç temel işlevi 'proje yönetimi' olan Proje Yönetimi Ofisi (PMO) veya benzeri bir yapı içerisinde görev aldınız mı?

(Sadece bir seçeneği işaretleyiniz.)

- o Evet
- o Hayır

4. Proje yönetimi ile ilgili bir sertifikaya sahip misiniz? Sahipseniz hangisi?

(Bir ya da birden çok seçim yapabilirsiniz.)

- o PMP
- o CAPM
- o PRINCE2
- o Diğer _____
- o Sertifikaya sahip değilim

5. Bugüne kadar kaç proje içerisinde yer aldınız ?

(Sadece bir seçeneği işaretleyiniz.)

- o 0-5
- o 6-10
- o 11-20
- o 20'den fazla

6. Bugüne kadar yer aldığınız proje yönetimi faaliyetlerinde metodların kullanılma sıklığı nedir?

(Sadece bir seçeneği işaretleyiniz.)

- o Hiçbir projede metod kullanılmadı
- o Az sayıda projede metod kullanıldı
- o Projelerin yaklaşık yarısında metod kullanıldı
- o Projelerin çoğunluğunda metod kullanıldı
- o Bütün projelerde metod kullanıldı

7. Firmanızda temel işlevi 'proje yönetimi' olan Proje Yönetimi Ofisi (PMO) veya benzeri bir yapı bulunmakta mıdır?

(Sadece bir seçeneği işaretleyiniz.)

- o Evet
- o Hayır

8. Firmanızda proje yönetiminde belirli metodlar kullanılıyor ise metodun seçimi genellikle neye göre yapılmaktadır? (Belirleyicilik bakımından 1-5 arası puan veriniz.)

1: Hiç belirleyici değil 5: Çok belirleyeci; bilmiyorsanız boş bırakınız

(Her satırda sadece bir seçeneği işaretleyiniz.)

	1	2	3	4	5
Projenin büyüklüğü					
Proje ekibinin bir araya					
gelebilme sıklığı					
Müşterinin çalışmalara ne					

kadar dahil edilebildiği/iletişim					
seviyesi					
İhtiyaçların netlik derecesi					
Projenin kısıtları					
Riskler					
Karmaşıklık seviyesi					
Kullanılan araçlar					
Kurum kültürüne uygunluk					

9. Bugüne kadarki çalıştığınız kurumlarda proje yönetiminde kullanılacak yöntemler ağırlıklı olarak kimin tarafından belirlenmektedir ?

(Sadece bir seçeneği işaretleyiniz.)

- o Proje yöneticisi
- o Proje ekibinin ortak görüşleri
- o Şirket yönetimi
- o Ürün sahibi/ müşteri
- o Halihazırda şirket kültürüne yerleşmiş yöntemler kullanılır, seçim yapılmaz

10. Bugüne kadar çalıştığınız kurumlarda yürütülen projelerde, aşağıda bulunan yaklaşım/metod/tekniklerin kullanılma durumunu belirtebilir misiniz ?

(Her satırda sadece bir seçeneği işaretleyiniz.)

	Kullanıldı	Kullanılmadı
Waterfall (geleneksel)		
Agile yaklaşımı türevleri (Scrum, XP, Kanban , Lean		
vb.)		
PRINCE2		
CCPM (Critical Chain Project Management-		

Kritik Zincir		
Proje Yönetimi)		
PMI PMBOK		
Six Sigma		
CPM (Critical Path- Kritik yol metodu)		
PERT tekniği		
GANTT Chart		
Kurum tarafından geliştirilmiş metodlar		
Bilinen metodlardan türetilmiş hibrid metodlar		

11. Eğer bir önceki soruda, CCPM için "kullanılmadı" seçeneğini işaretlediyseniz; CCPM bugüne kadar kurumunuzda kullanılması önerilen/değerlendirilen/tartışılan bir opsiyon oldumu?

CCPM : Critical Chain Project Management (Kritik Zincir Proje Yönetimi)

(Sadece bir seçeneği işaretleyiniz.)

Evet
Hayır
Bilmiyorum

12. CCPM (Kritik Zincir Proje Yönetimi) yaklaşımına ilişkin bilginiz hangi seviyededir?

- (Sadece bir seçeneği işaretleyiniz.)
- Hiç bilgim yok
- Çok az bilgim var
- Temel özelliklerini biliyorum
- Uygulayacak kadar detaylı biliyorum
- Tüm detaylarına oldukça hakimim

13. Lütfen aşağıdakilerin her biri için, proje yönetiminde izlenen bir methodolojiden beklenen faydalar anlamında önem bakımından derecelendiriniz

    1: Hiç önemli değil 5: Çok önemli; bilmiyorsanız boş bırakınız

    (Her satırda sadece bir seçeneği işaretleyiniz.)

	1	2	3	4	5
Projelerin daha kısa sürede					
tamamlanmasını sağlaması					
Projelerin zamanında teslim					
edilmesini artırması					
Çalışma ortamında stresin					
azaltılması					
Projelerin tamamlanma					
şansını artırması					
Proje verimini artırması					
Projeler için kapsam					
değişikliklerini minimuma					
indirmesi					
Proje maliyet artışlarını					
minimize etmesi					
Kaynaklar için multi-tasking					