PROJECT MANAGEMENT METHODOLOGIES FOR NEW PRODUCT DEVELOPMENT

A Thesis

by

Mert Kıranç

Submitted to the

Graduate School of Sciences and Engineering
In Partial Fulfillment of the Requirements for
the Degree of

Master of Science

in the
Department of Industrial Engineering

Özyeğin University
May 2018

PROJECT MANAGEMENT METHODOLOGIES FOR NEW PRODUCT DEVELOPMENT

Approved by:

Professor Ekrem Duman, Advisor,
Department of Industrial Engineering
Özyeğin University

Professor Yasemin Claire Erensal,
Department of Industrial & Systems Engineering
Yeditepe University

Assistant Professor Erinç Albey,
Department of Industrial Engineering
Özyeğin University

Date Approved: 14 May 2018

ABSTRACT

This thesis intends to create an integrated project management methodology for the ones who focus on new product development projects. In order to build an integrated methodology, four different management systems are combined. These systems are called as “Schedule-oriented Stage-Gate Method, Risk Management, Change Management and Earned Value Management”.

New product development term is quite common in many different industries such as defense industry, construction, health care/dental, higher education, fast moving consumer goods, white goods, electronic devices, marketing & advertising and software development. All product manufacturers run against each other’s for introducing a new product to the market. In order to achieve to produce a more competitive product in the market, an optimum project management methodology is chosen and this methodology is adapted to company culture. The right methodology helps the company to present perfect product to the customers at the right time.

The thesis starts to describe the project management concept and the evolution of project management. Literature review on the project management methodologies and new product development follows the first description. In the following chapter, popular project management methodologies are presented to researchers in details. The methodologies are categorized depending on the requirements of different kind of projects. Which methodology is mostly fitted to new product development projects is discussed. After research, it is seen that only one methodology does not meet the requirements of the new product development projects. Hence, a new integrated project management methodology is introduced. All methodologies which are included by the integrated methodology are described separately and then these methodologies are linked to each other’s to build the integrated one. The benefits of proposed methodology are discussed as an application by a company. As a result, how the integrated methodology improves the efficiency and how it achieves the success of the project are unfolded.

Keywords: Project, project management, management methodology, new product development, risk management, change management, earned value, stage-gate.

ÖZETÇE

Bu tez, yeni ürün geliştirme projeleri üzerinde çalışanlar için entegre bir proje yönetim metodolojisi yaratmayı amaçlamaktadır. Entegre bir metodoloji yaratmak için dört farklı yönetim sistemi bir araya getirilmiştir. Bu yöntemler şu şekilde adlandırılabilir: "Takvim Bazlı Aşama-Değerlendirme Metodu, Risk Yönetimi, Değişim Yönetimi ve Kazanılmış Değer Yönetimi".

Yeni ürün geliştirme, savunma sanayisi, inşaat, sağlık, yükseköğrenim, hızlı tüketim eşyaları, beyaz eşya, elektronik cihazlar, reklamcılık ve yazılım geliştirme gibi sektörlerde ortak olarak kullanılan bir terimdir. Tüm üreticiler markete yeni bir ürün çıkarmak için birbirleriyle rekabet halindedir. Markette daha rekabetçi bir ürün yaratmak için en uygun proje yönetim metodu seçilir ve bu metot şirket kültürüne adapte edilir. Doğru metot şirketlere, mükemmel ürünü müşterilerine doğru zamanda sunmaları konusunda yardımcı olacaktır.

Tez ilk olarak proje yönetim konseptini ve proje yönetiminin evrimsel sürecini anlatmaktadır. Bu anlatım sonrasında, proje yönetim metodolojileri ve yeni ürün geliştirme konuları üzerine yapılan literatür araştırmaları paylaşılmaktadır. Bir sonraki bölümde, popüler proje yönetim metodolojileri detaylı bir şekilde araştırmacılara sunulmaktadır. Metodolojiler, farklı türde projelerin gereksinimlerine göre kategorize edilmektedir. Hangi metodolojinin yeni ürün geliştirme projelerine daha uygun olduğu tartışılmaktadır. Araştırmanın sonucuna göre, yeni ürün geliştirme projelerinin yönetiminde sadece tek bir metodolojinin yeterli olmayacağı görülmektedir. Bu nedenle, yeni bir entegre proje yönetim metodolojisi tanıtılmaktadır. Entegre metodolojinin içerdiği tüm metotlar bağımsız olarak anlatılmakta ve sonra birbiriyle ilişkilendirilmektedir. Önerilen metodu uygulayan bir şirket üzerinden metodun faydaları tartışılmaktadır. Sonuç olarak, önerilen bu entegre metodolojinin verimliliği nasıl arttırdığı ve projenin başarısına nasıl olumlu katkıda bulunduğu gözler önüne serilmiştir.

Anahtar sözcükler: Proje, proje yönetimi, yönetim metodolojisi, yeni ürün geliştirme, risk yönetimi, değişim yönetimi, kazanılmış değer, aşama-değerlendirme

ACKNOWLEDGMENTS

I would like to express my deepest gratitude and thanks to my advisor, Prof. Dr. Ekrem DUMAN, for his continuous support, excellent guidance and valuable advice throughout the progress of this thesis.

I would also like to express my thanks to Murat ÖZBİLEN, PMP, Senior Partner at Global Business Management Consultants for his great assistance and perfect guidance throughout the progress of this thesis.

Finally, I am deeply indebted to my wife, my family and my friends for their encouragement and continuous support.

Mert KIRANÇ

TABLE OF CONTENTS

ABBREVIATIONS

PM : Project Management

NPD : New Product Development

PMO: Project Management Office

EVM: Earned Value Management

LSS : Lean Six Sigma

VSM: Value Stream Map

PERT: Program Evaluation and Review Techniques

CPM: Critical Path Method

PDM: Precedence Diagram Method

GERT: Graphical Evaluation and Review Techniques

WBS: Work Breakdown Structure

CPI: Cost Performance Index

SPI: Schedule Performance Index

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 General Overview

Nowadays, nearly all companies develop their own methodology to increase the efficiency of project management adaptation to the projects and reduce time-to-market of an innovation or renovation product. Even some companies build a project management office (PMO) as a new department. This office creates a government structure to manage all the new projects and also it makes contact with companies which offer consultancy service to improve the current methodology consistently.

There are so many single project management methodologies such as Agile, Waterfall, Six Sigma, State-gate, PMBOK, Prince2, Spiral and Scrum. All these methods can be used for different types of projects depending on the requirements of the project from both developer's and customer's point of view. A company, which integrates a few of these methods and blends them with its corporate culture, achieves to implement the best practice for project management.

Selection and implementation of a correct methodology plays a big role in maximizing productivity in a new product development (NPD) process. Generally, it is the best way to split a long-term NPD project into stages and apply the proper project management methodology for each stage and even for group of items inside the stages. This approach requires a combined project management (PM) methodology instead of pushing all stages by a particular PM methodology. Robert Cooper and Scott Edgett, who are the creators of Stage-gate system, present "seven principles of lean NPD" with the goal of improving productivity [16]. Generally, these principles lay emphasis on customer value and being agile to rapid changes of the customer's needs. The principles also emphasize iterative development and continuous improvement through Nexgen Stage-gate process. Effective cross-functional team is the key point to implement these principles in a successful way. Figure 1.1 presents seven principles of lean NPD.

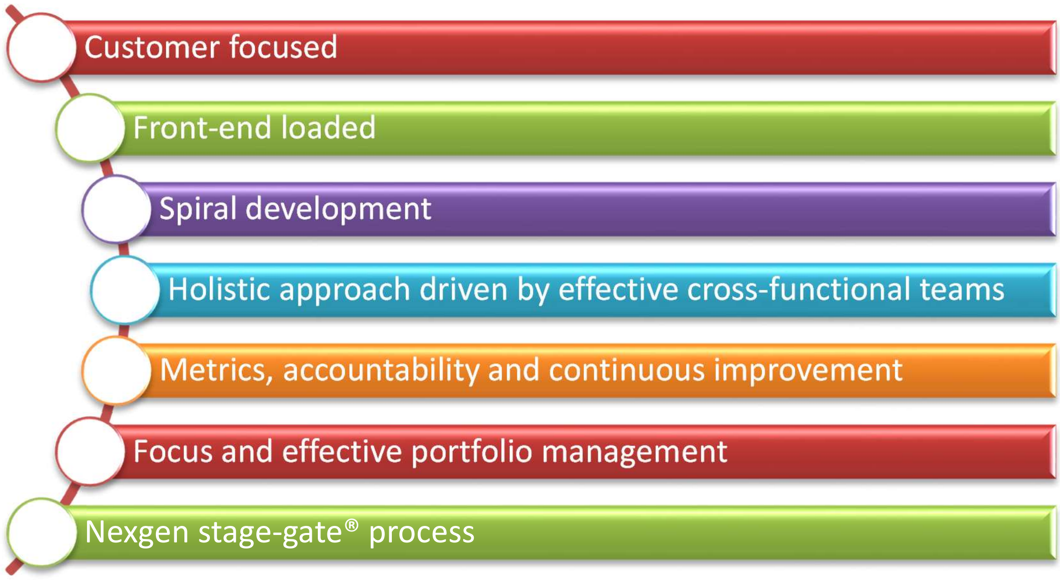


Figure 1.1 Seven principles of lean NPD

1.2 Project Management Concept

The word "project" comes from the Latin word "projectum" and it originally means "before an action" [2]. Therefore, it refers to a planning process of something before taking an action.

Project Management Institute (PMI) defines "project" as a temporary endeavor undertaken to create a unique product, service or result [1]. Project objectives reveal a target status at the end of the project whether they have been achieved or not. These objectives can be called as "SMART criteria": Specific, Measurable, Achievable, Realistic and Time-Based [2].

In many industries, companies apply their own project management methodology during a product life cycle. People who work in these companies misunderstand the project management concept since they already have ongoing projects and think that they use project management to control life cycle phases. In this case, the definition might be [4]:

Project management is the art of creating the illusion that any outcome is the result of a series of predetermined, deliberate acts when, in fact, it was dumb luck.

Clearly, this definition does not refer to a real project management concept. The right definition of project management is presented as:

Project management is the planning, organizing, directing, and controlling of company resources for a relatively short-term objective that has been established to complete specific goals and objectives.

Figure 1-2 shows that project management is designed to manage or control company resources on a given activity, within time, within cost, and within performance in good customer relations [4]:

Figure 1.2 Project management dynamics within good customer relations

1.3 Evolution of Project Management

From the origin to nowadays, project management has been supported by new processes changing year by year. Kernzer (2009) defines new processes that have an increasing support on project management between 1985 and 2009 [4].

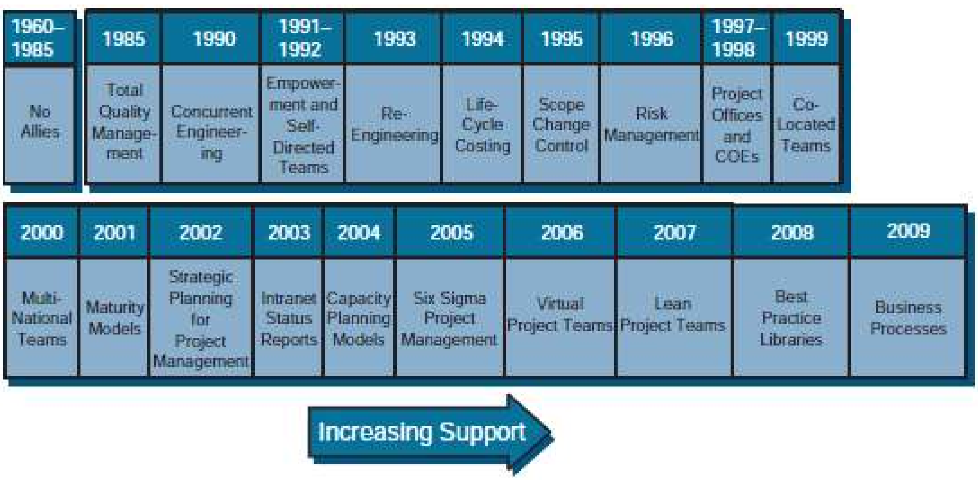


Figure 1.3 New processes supporting project management

In terms of main subject of this thesis, some of the new processes are clarified below:

- **1990:** Advocates of concurrent engineering begin promoting the use of project management to obtain better scheduling techniques [4]. Concurrent engineering (CE) is one of the new product development processes that requires the involvement of cross-functional teams starting with initial development stages to plan for product development and manufacturing processes simultaneously [5]. CE is classified as point-based and set based. Point-based approach is generally preferred by original equipment manufacturers (OEMs). In this approach, the best conceptual design is selected and frozen in the beginning. In the set-point approach (developed and implemented by Toyota), the company develops a set of alternatives and eliminates gradually until converging to a final design [6].

- **1995:** Companies recognize that very few projects are completed within the framework of the original objectives without scope changes. Methodologies are created for effective change management [4]. Uncertainties that appear during new product development (NPD) projects cause some changes in the scope. A popular methodology to managing the uncertainty inherent in product development is to have a checkpoint or decision gate at the end of major stages. The stage-gate methodology applies concurrent engineering and sets mandatory activities for various stages [7].

- **2005:** The techniques utilized in Six Sigma are being applied to project management, especially for continuous improvement to the project management methodology. This will result in the establishment of categories of Six Sigma applications some of which are nontraditional [4].

- **2007:** The concepts of lean manufacturing will be applied to project management [4]. Lean principles, widely recognized as the essential principles of the Toyota Production System (TPS), have been successfully embraced by the manufacturing arm of Toyota Motor Corp [5]. Lean thinking is based on eliminating non-value added activities in the NPD process.

- **2008:** Companies will recognize the value of capturing best practices in project management and creating the best practices library or knowledge repository [4]. Survival of the firm has become the most important reason today for capturing best practices. There are nine best practices activities as shown in Figure 1-4, and most companies that recognize the value of capturing best practices accomplish all of these steps [8].

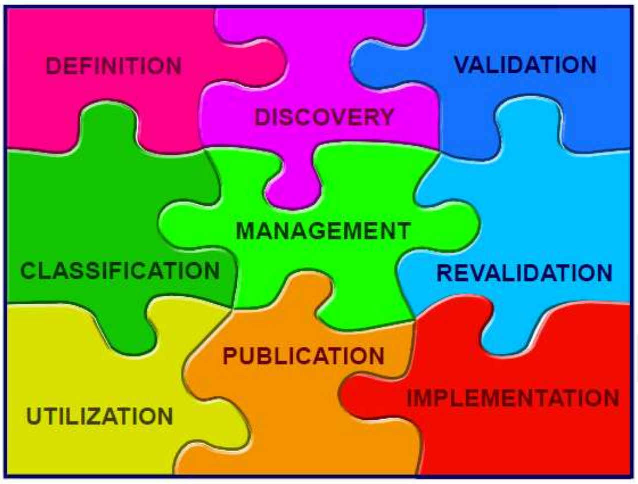


Figure 1.4 Best practices processes

- **2009:** Project management methodologies will include more business processes to support project management [4].

1.4 Guidelines and Benefits of Thesis Research

This thesis intends to create a project management methodology for practitioners and researchers who focus on new product development projects. After literature research is finalized, outputs canalize the research to set up an integrated project management methodology. This methodology will be presented in details in terms of maximizing efficiency and reducing time-to-market of an NPD project. This integrated project management methodology involves four main parts:

- *Schedule-oriented Stage-Gate Method:* Stage-gate is one of the common project management methodologies for NPD. But it is presented with new approach of scheduling stages and gates in the thesis.
- *Risk Management:* It is useful to predict possible risks and mitigate them during the projects.
- *Change Management:* There exist the requirements of some changes regarding unexpected results and customer's variable needs during the project. This method is used to create "change gates" adding to decision gates in the thesis.
- *Earned Value Management:* EVM is a management technique that is used for measuring the performance of the project in terms of technical, cost and schedule targets.

This study presents favorable information on project management for new product development projects to the academicians. Integrated project management methodology will be a good reference for future studies.

CHAPTER II

LITERATURE REVIEW

2.1 Project Management Methodologies

Project management methodology is a repetitive process that can be used for any kind of projects to achieve project management excellence or maturity [4]. The chosen methodology should be practical for the members of the project team to be able to use throughout their projects. Many project managers have found that, in practice, you cannot simply use a methodology exactly as it stands. They soon realized that they needed to modify the methodology they selected to suit their own company's project needs [9].

Developing a standard project management methodology does not include all companies. For the companies which have short-term projects, developing a formal methodology is not cost effective. Contrary to this, for companies which manage large and complex projects, it is an undoubted necessity to develop and implement a project management system [4]. Today, such excellent companies as Nortel, Ericsson and Johnsons Controls Automotive integrate five main management processes to build a good methodology, as shown in Figure 2.1 [4-8].

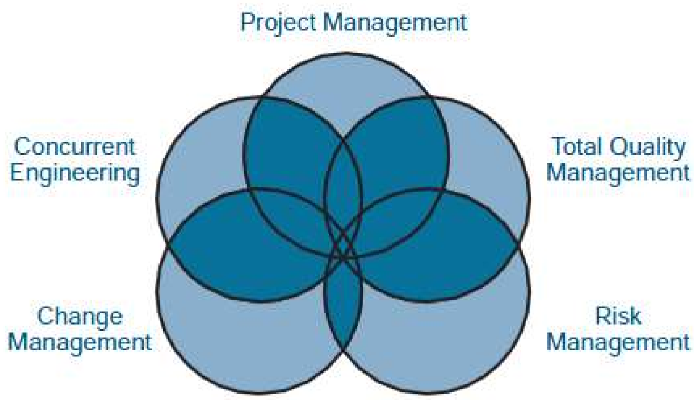


Figure 2.1 Processes integrated into PM methodology

- *Project Management:* The basic principles of planning, scheduling, and controlling work.
- *Total Quality Management:* The process of ensuring that the last result will meet the quality expectations of the customer.
- *Concurrent Engineering:* The process of performing work in parallel rather than series in order to compress the schedule without incurring serious risks.
- *Scope Change Control:* The process of controlling the configuration of the last result so that value added is provided to the customer.
- *Risk Management:* The process of identifying, quantifying, and responding to the risks of the project without any material impact on the project's objectives.

Methodologies should be designed to support the corporate culture, not vice versa. Any methodology can be converted into a world-class methodology via its adaptability to the corporate culture. Sometimes even if the simplest methodology is used correctly, it contributes to increase the chance of success. For example, Swagelok Company - a manufacturer of gas and fluid systems components - has developed a simple checklist system with phase reviews, called as "Checkpoint" and supported that methodology with training and education [8].

Selecting, developing and implementing of project management methodologies will be elaborated and discussed in the following chapters.

2.2 New Product Development (NPD)

The US based Product Development & Management Association (PDMA) defines New Product Development as "a disciplined and defined set of tasks and steps that describe the normal means by which a company repetitively converts embryonic ideas into saleable products or services" [11].

New product development term (NPD) is quite common in lots of different industries and even different environments such as defense industry, construction, health care/dental, higher education, fast moving consumer goods, white goods, electronic devices, marketing & advertising, software development and many of product manufacturers which have the same goal of introducing a new product to the market. Some companies choose a methodology and try to integrate it into the company culture. However, some companies have their own methodology to manage a project of NPD and use some project management tools which are fitted to the company culture.

Whereas the cost is the primary focus in project management, both cost and income are considered in making strategic decisions for NPD projects [7]. Generally, companies work on several projects and sometimes there exists a need of eliminating some projects since available funding is enough to support only a few ones. Hence, the company should make a decision on which project to be worked on in the pool next. This refers to project portfolio management process [8]. Portfolio management involves the consideration of the aggregate costs, risks and returns of all projects within the portfolio and it helps to determine the right mix of the projects and the right investment level to make in each of them [10]. The Figure 2.2 demonstrates a typical portfolio matrix that gains the ability to compare and contrast dissimilar projects with a very little effort [8].

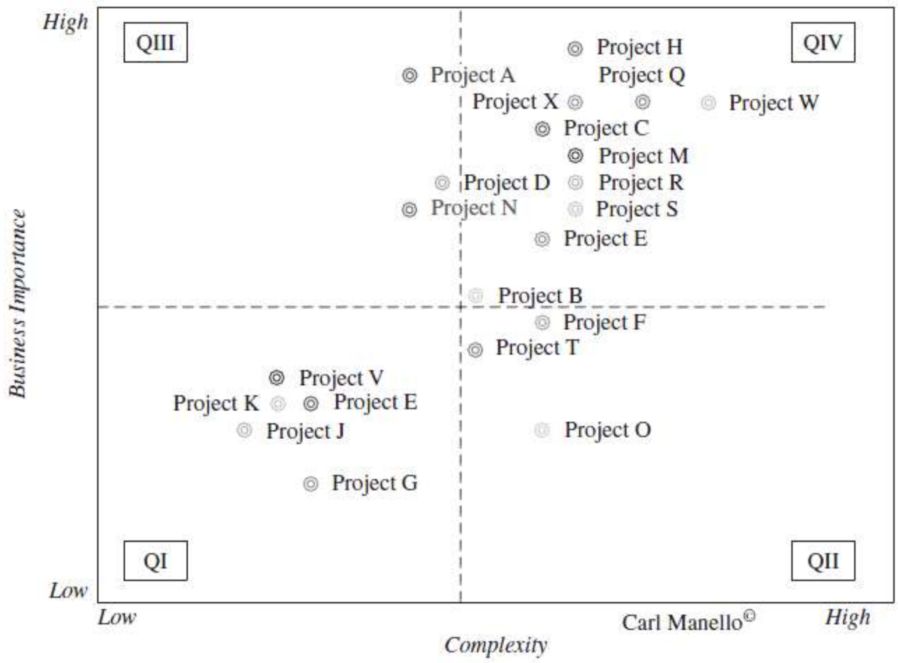


Figure 2.2 Typical portfolio matrix

As the matrix is interpreted, QIV region has maximum accumulation of projects which have more business importance, but also high complexity. For project managers, this matrix is useful to eliminate some of the projects simply and then judge the importance of other projects in terms of cost and returns.

The development phase is concerned with both component and product prototype testing. Generally, after the component specifications are finalized, prototypes are developed in order to organize tests to give initial verifications of the component on appliance. In many of industries, the following tests are generated [13];

- *Environmental testing/demonstration:* Temperature cycling, shock and vibration, humidity, sand and dust, salt spray, acoustic noise, explosion proofing, and electromagnetic interference.
- *Reliability testing/demonstration:* Sequential testing, life testing, environmental stress screening and reliability growth testing.
- *Pre-production tests/demonstrations:* Implemented to verify that the component may be produced and to reveal potential production problems, and ensure that the component produced has the desired performance.

After the product prototypes become available, Hamid et al. (1993) proposes a range of tests to verify product performance [13]. Even if the approach is old, the similar processes are still applied in the industries of NPD just as mentioned in this thesis at the case study of X product. The prominent tests and checks are; "pre-assembly tests and evaluation" that ensures seamless assembly of product, "field tests" that gives the opportunity of observing the conditions of end-user environment and "market pre-launch" that provides to verify if the product meets customer expectations.

Following sub-parts present how the product range shapes, an introduction to organizational change management in project management of NPD and prominent project management methods for NPD.

2.2.1 Product Classification

There are different approaches from researchers to classify products in terms of manufacturers and customers. Murthy et al. categorizes products into four groups [12]:

- *Consumer nondurables:* These are bought by individuals for consumption, such as food items, cosmetics, and clothes.
- *Consumer durables:* Society at large, as well as commercial users and government agencies all consume these types of products (e.g., computers, television sets, appliances, automobiles).
- *Industrial and commercial products:* Industrial and commercial products (e.g., large-scale computers, cutting tools, pumps, X-ray machines, commercial aircraft, and hydraulic presses) are characterized by a relatively small number of consumers and manufacturers. The technical complexity of such products and the mode of usage can vary considerably.
- *Specialized defense-related or industrial products:* Specialized products (e.g., military aircraft, ships, and rockets) are usually complex and expensive and involve "state-of-the-art" technology with considerable R&D effort required of the manufacturers. Customers are typically one or few governments or industrial businesses, and there are a relatively small number of manufacturers.

In this thesis, the case study of X product is in the category of consumer durables that includes prominent industrial products such as permanent magnet motor, a new design door lock and advanced heating system.

Hamid et al. (1993) suggests another classification type that is based on structure of design process [13]:

- *Creative designs:* Creative design is an abstract decomposition of the design problem into a set of levels that represent choices for the problem.
- *Innovative designs:* Design might be an original or unique combination of existing components. A certain amount of creativity comes into play in the innovative design process.

- *Redesigns:* An existing design is modified to meet the required changes in the original functional requirements.
- *Routine designs:* A priori plan of the solution exists. The subparts and alternatives are known in advance, perhaps as the result of either a creative or innovative design process. Routine design involves finding the appropriate alternatives for each subpart that satisfies the given constraints.

2.2.2 Organizational Change Management for NPD

New product development projects, especially the innovative ones are really hard to manage because of the requirement of high experience on change management methodology. Why is that? The answer is simple; NPD projects have so many uncertain outcomes after each critical phase of the project. These uncertain outcomes cause the scope of the work to be dynamic [7]. In conventional project management, the scope and outcomes are defined at the beginning and project scope management is implemented within characteristic lines. PMBOK® guide defines "project scope management" in five processes [1];

- ✓ Collect Requirements
- ✓ Define Scope
- ✓ Create WBS (Work Breakdown Structure)
- ✓ Verify Scope
- ✓ Control Scope

Briefly, these processes are not enough to manage NPD projects. When critical changes occur on project scope, especially WBS must be revised regarding new requirements. Therefore, the management system cannot be steady-state; it should always be dynamic. Simply, "Create WBS" is the process of subdividing project deliverables and project work into smaller, more manageable components [1]. It is presented as a sample WBS of a universal motor development project for washing machine in Figure 2.3 below:

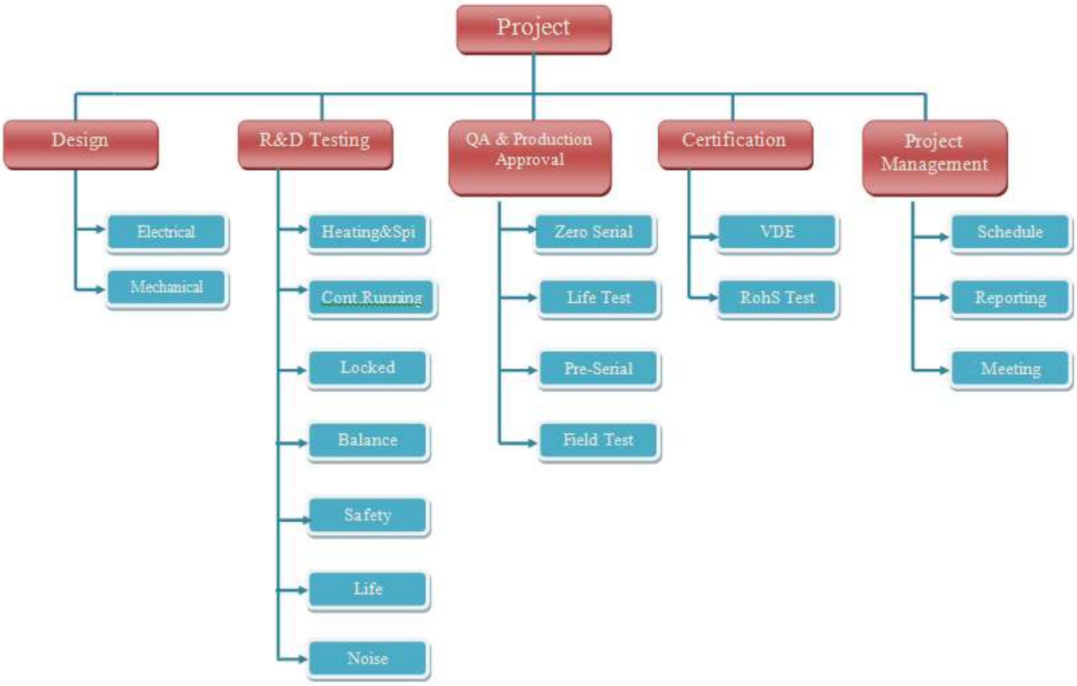


Figure 2.3 Sample work breakdown structure (WBS)

Corporate companies include different functional units that manage different parts of the total business. These units differentiate from each other's from not project driven to project driven. Not project-driven units feel threatened by project management and put up resistance to methodology of PM. Figure 2.4 shows the level of resistance to change for different functional units of a corporate company [4].

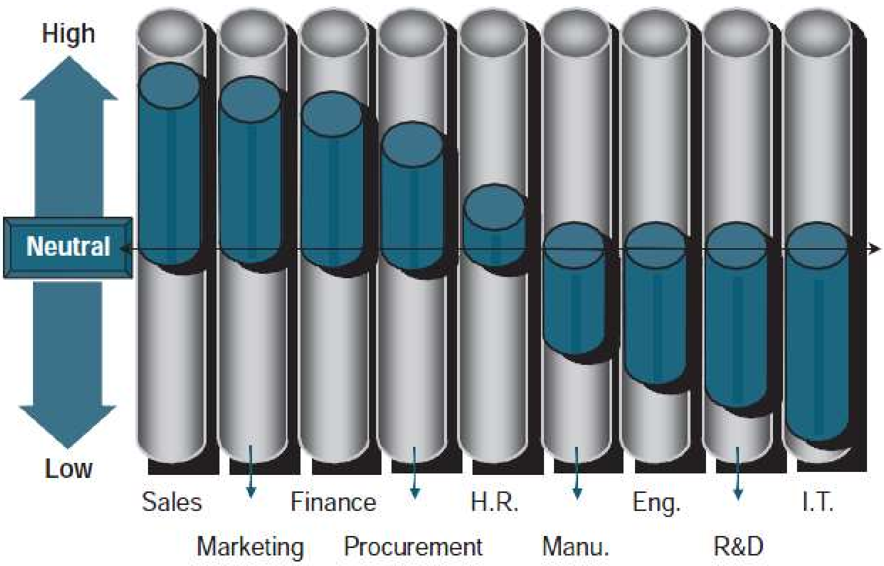


Figure 2.4 Resistance to change

- *Sales:* The sales staff's resistance to change arises from fear that project management will take credit for corporate profits, thus reducing the year-end bonuses for the sales force. Sales personnel fear that project managers may become involved in the sales effort, thus diminishing the power of the sales force.
- *Marketing:* Marketing people fear that project managers will end up working so closely with customers that project managers may eventually be given some of the marketing and sales functions. This fear is not without merit because customers often want to communicate with the personnel managing the project rather than those who may disappear after the sale is closed.
- *Finance (and Accounting):* These departments fear that project management will require the development of a project accounting system (such as earned value measurement) that will increase the workload in accounting and finance, and that they will have to perform accounting both horizontally (i.e., in projects) and vertically (i.e., in line groups).
- *Procurement:* The fear in this group is that a project procurement system will be implemented in parallel with the corporate procurement system, and that the project managers will perform their own procurement, thus bypassing the procurement department.
- *Human Resources Management:* The HR department may fear that a project management career path ladder will be created, requiring new training programs. This will increase their workloads.
- *Manufacturing:* Little resistance is found here because, although the manufacturing segment is not project-driven, there are numerous capital installation and maintenance projects which will have required the use of project management.
- *Engineering, R&D, and Information Technology:* These departments are almost entirely project-driven with very little resistance to project management.

One of the most important benefits of developing a change management process is to give companies a chance to manage the customers. In case a customer requests some changes on the project scope, project manager must directly inform the customer as to the impact of this change on schedule, safety, cost and technical performance. Therefore, the customer can be able to be educated on how the methodology of company works [8].

In companies which apply project management process excellently, risk management and change management are enforced concurrently throughout the life cycle of the project. By this way, the impact on product quality, cost and timing can be continuously reported to management quickly [8]. According to Charvat (2003), companies need a "project change steering group" who reviews the implementation of all changes to the project. Figure 2.5 represents a life cycle of responsibilities of change steering group [9].

How the change management process is implemented to a project and how it is combined with other project management methodologies will be under discussion on the following chapters of this thesis.

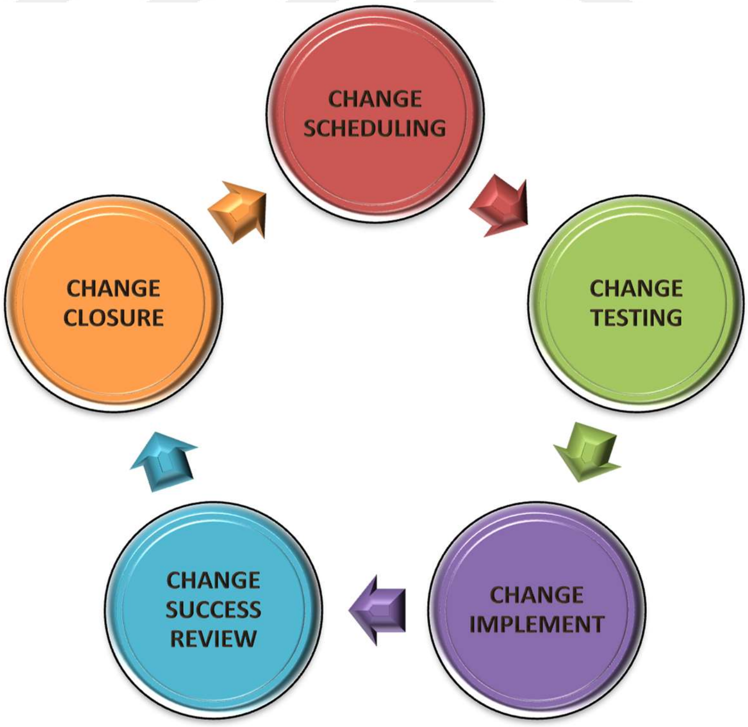


Figure 2.5 Life cycle of responsibilities of change steering group

2.2.3 Project Management for New Product Development

In literature, there are so many project management methodologies that a project manager can consider managing any kind of projects. Choosing the correct methodology plays a big role in order to mitigate the negative effects of failures/changes on cost, budget and schedule in a project. Charvat (2003) presents a list of prominent requirements to select a methodology in the Table 2.1 [9].

► *Budget:* Budgets play a big role in any project, and the type of methodology to be used is significant. For example, a sponsor says, "Money is no problem; we need this product by the end of the year." If a heavy methodology is selected, the company may not achieve its goal because it will see the results only near the end of the project. Instead, an agile methodology may be the more appropriate choice.

Requirement	Rationale
Budget	Methodologies require money and effects schedule.
Team size	Number of staff to be managed is required.
Project criticality	The urgency of the project decides the methodology.
Technology used	Hardware such as computer servers, composite materials, or electronics may be needed.
Documentation	The methodology needs documentation.
Training	Effective training to key support staff and project managers is required.
Best practices/lessons learned	Past lessons learned and good practices should be available.
Tools and techniques	Tools and techniques must be available.
Examination of existing processes	The maturity of existing processes will influence the pace at which a project will progress.
Software	Methodologies require software as part of their design.

Table 2.1 List of prominent requirements to select a methodology

► *Team size:* Methodologies are directly proportional to the team size. Light methodologies are useful for smaller teams but heavy methodologies are useful for larger teams. For example, the Boston Big Dig project, the largest underground artery roadwork project in the U.S. history estimated at $14.5 billion for 7.5 miles of highway requires thousands of workers across many vendors and employment agencies. A lightweight methodology is not suited to such a project.

► *Technology used:* The technology used on a project affects the direction and type of the methodology selected. On many projects today, simulation and testing of new technologies are actually considered a phase of the methodology.

► *Tools and techniques:* Some project methodologies require more tools and techniques than others. If a project manager must manage multiple design changes, he or she will need a configuration management tool and technique.

► *Project criticality:* The project might require additional resources to be finished by the required date. If the methodology is too small, the project manager loses control; if it is too large and formal, he or she slows the project down. A project manager's experience and skills will help in choosing the best approach.

► *Existing processes:* In any company, the maturity of existing project processes largely influence the methodology. For example, if a company follows the standard internal purchasing process which has a lead time of two months to receive goods, this process requires intervention in order to prevent it to slow down the project.

Pons (2008) focuses on the intersection of PMBOK® guide and research on new product development in his article. PMBOK® guide identifies nine knowledge areas where management is necessary: project integration, scope, time, cost, quality, human resources, communications, risk, and procurement [1]. After analyzing these knowledge areas, the research shows that project management incompletely meets the needs of NPD since there are large uncertainties in project path. Project evaluation and review technique (PERT) and critical path method (CPM) are useful methods for innovative projects but have significant gaps to overcome uncertainties. Stage-gate methodology is a popular approach to manage uncertainties but not enough as single-handed. Lean product development (LPD) is another approach that seeks primarily to reduce waste, improve the production process and reduce inventory with just-in-time (JIT) production. Whether lean project management is suitable for NPD is less clear. Design structure matrix (DSM) can be a good method for better handling of tasks in NPD but it is needed to be improved for complete project management [7].

Jennifer et al. (2011) defines LPD as “the cross-functional design practices (techniques and tools) that are governed by the philosophical underpinnings of lean thinking – value, value stream, flow, pull, and perfection – can be used (but are not limited) to maximize the value and eliminate the waste in new product development”. DSM provides valuable information for project managers interested in coordinating the activities of complex projects such as LPD project. In this article, it is also emphasized that transforming a classical NPD process into LPD process is much more complex and difficult than transforming an assembly line to a lean manufacturing process since LPD implementations need a wide change in organizational culture, tools and techniques in use and work processes that dominates all project management activities. In addition to that, LPD process also requires contributions from different areas which are classified into seven knowledge domains in the article; *“Performance-Based Domain”, “Decision-Based Domain”, “Process-Modeling Domain”, “Strategy Domain”*, *“Supplier/Partnership Domain”, “Knowledge-Based Networks Domain” and “Lean Manufacturing-Based Domain”* [14]. By the help of these knowledge domains, the article summarizes the evolution of LPD body of knowledge between 1990 and 2011.

Nepal et al. (2011) integrates traditional lean manufacturing tools like value-stream mapping (VSM) with other Six Sigma and project management tools, such as the cause and effect matrix and the design structure matrix (DSM). The VSM is mainly employed for identifying the non-value-added activities (NVAs) such as reworks and waiting. In the next stage, the DSM is created to facilitate understanding of the nature and the root causes of those NVAs. Lastly, the cause-and-effect matrix is used to prioritize the root causes by determining the significance level of an activity with respect to its impact on NPD process performance. After all these points are clarified, a two-phase improvement plan is applied to NPD process and totally 68% reduction in NPD cycle time is enhanced. Plan of process improvement projects is shared in Table 2.2 [5].

Project	Relative Impact	2006 Q3	2006 Q4	2007 Q1	2007 Q2	2007 Q3	Improvement Area
Develop and Implement a Cross-functional NPD Capacity Management System	High						Wait, Rework
Develop and implement a robust front-end process	High						Wait, Rework
Improve Supplier NPD development system, including Supplier qualification, relationships and joint accountability.	Medium						Wait
Improve implementation process (Design hands off to Production)	Medium						Wait, Rework
Improve Program/Project Management Skill Set	Meduim						Wait, Rework, NVA
Integrate a common product lifecycle management system	High						Wait, Rework, NVA
Develop Standardized NPD methodologies	High						Rework
Create a system for continuously generating information for design development execution	Medium						Wait, Rework, NVA
Improve test and simulation capability	Medium						NVA
Speed Impact %		20%	50%	58%	61%	68%	

Phase 1 Projects   Phase 2 Projects

Table 2.2 Phase wise plan of process improvement projects

Valeri et al. (2004) reveals a new quality gate (a new generation of stage-gate) approach is called "flexible process-oriented approach". It is a third generation quality gate process that provides flexibility for the new product development process. Gates are events used to help companies to decide for the continuation or suspension of an NPD project. The basic stage-gate (phase-review) process is illustrated below in Figure 2.6 [15].

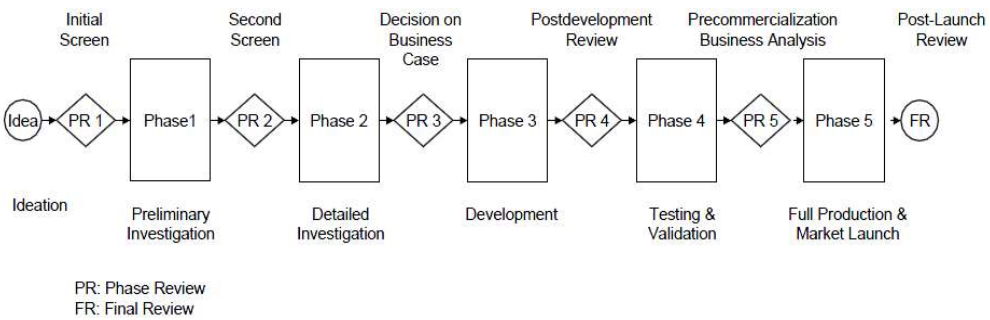


Figure 2.6 A generic phase review process

There are “deliverables” that reflect the results from preceding phase to the gates. In each gate, there is an “exit criteria” against what the project is judged in order to make decision of going, holding or killing the project.

The flexible process-oriented approach mentioned in this article includes five activities shown in Figure 2.7.

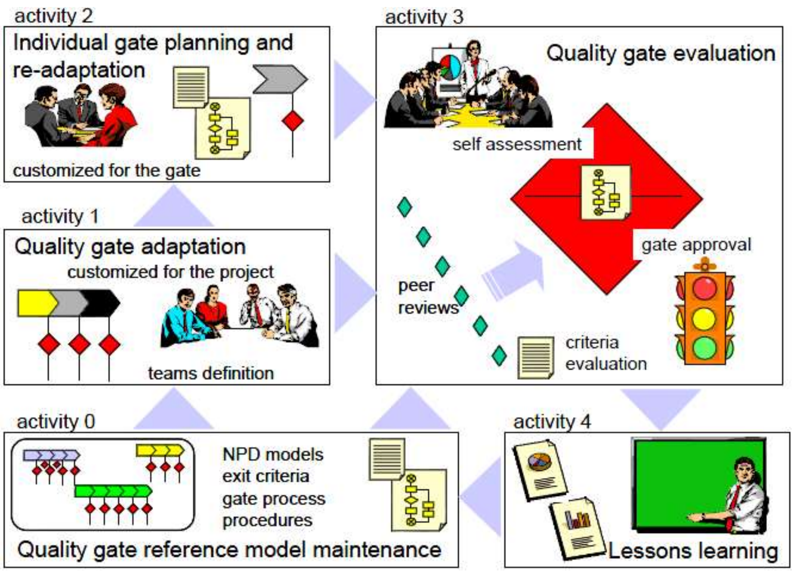


Figure 2.7 Activities of proposed gate process

Activity 0 - Quality gate reference model maintenance: This activity continues during whole process to ensure that the quality gate model always complies with the NPD reference model.

Activity 1 - Quality gate adaptation: This activity includes four steps; design phases and gates, defining exit criteria, defining gatekeepers and advisory team and defining the evaluation process. It confers flexibility on the NPD process.

Activity 2 - Individual quality gate planning and readaptation: This activity, which is necessary to adapt the project to changes that may occur during the development phases, makes the exit criteria and process evaluation flexible, increasing its adaptability to changes.

Activity 3 - Quality gate evaluation: This activity is a key factor for process flexibility and divided into three steps in order to evaluate a project phase strictly. These steps are “peer reviews” which are meetings to evaluate specific subjects or deliverables; “project self-assessments” which are the meetings, that involves the project manager, the NPD team leaders and the advisory team, in which detailed results of the peer reviews are summarized and each exit criterion is analyzed; “quality gate approvals” which are meetings in which final decision of “Go, Go Conditional, Redirect, Hold or Kill is made.

Activity 4 - Quality Gate Lesson Learning: In this activity, lessons learned about exit criteria of gates, the quality gate process and the NPD process are compiled, analyzed, classified and recorded. In the end, it is reviewed if the quality gate reference model (activity-0) needs improvements or not.

Finally, this article gives flexibility on the quality gate and proposes the overlap concept (i.e., tasks belonging next phase can start before the previous phase is finished) that reduces time to market and allows concurrent engineering practices. Consequently, the authors defend that the gate process proposed in the article can be considered as third generation approach depending on its flexibility.

Cooper et al. (2002) reveals five specific reasons that cause many companies not to be able to kill projects. The most popular reason is the pressure of sales who usually mention as losing customer if the project is canceled. The second reason is that there are no serious “Go/Kill/Hold on” decision points except from meetings and review points. The third reason is directly regarding decision point criteria to make a decision on prioritizing the projects. The fourth one is inadequate engagement of senior managers to make critical decisions. The last one is the most difficult case; all projects in hand are good and it is really hard to eliminate one of them [17].

New product system of a company is also presented in the article. The system is built on three versions of stage-gate process which are optimized regarding level of risk for the project. As much as the risk level of the project increases, the complexity of stage-gate model increases, too.

- *The SCR Process:* This process is engaged as a special customer request for some revisions on the product; it consists of two stages and two gates.
- *The Fast Track Process:* This process is applied to projects with moderate risk and it consists of three stages.

➢ *The Full Process:* It consists of five stages and implements for higher risky projects.

The Figure 2.8 illustrates the stage-gate models optimized for different risk level of projects [17]:

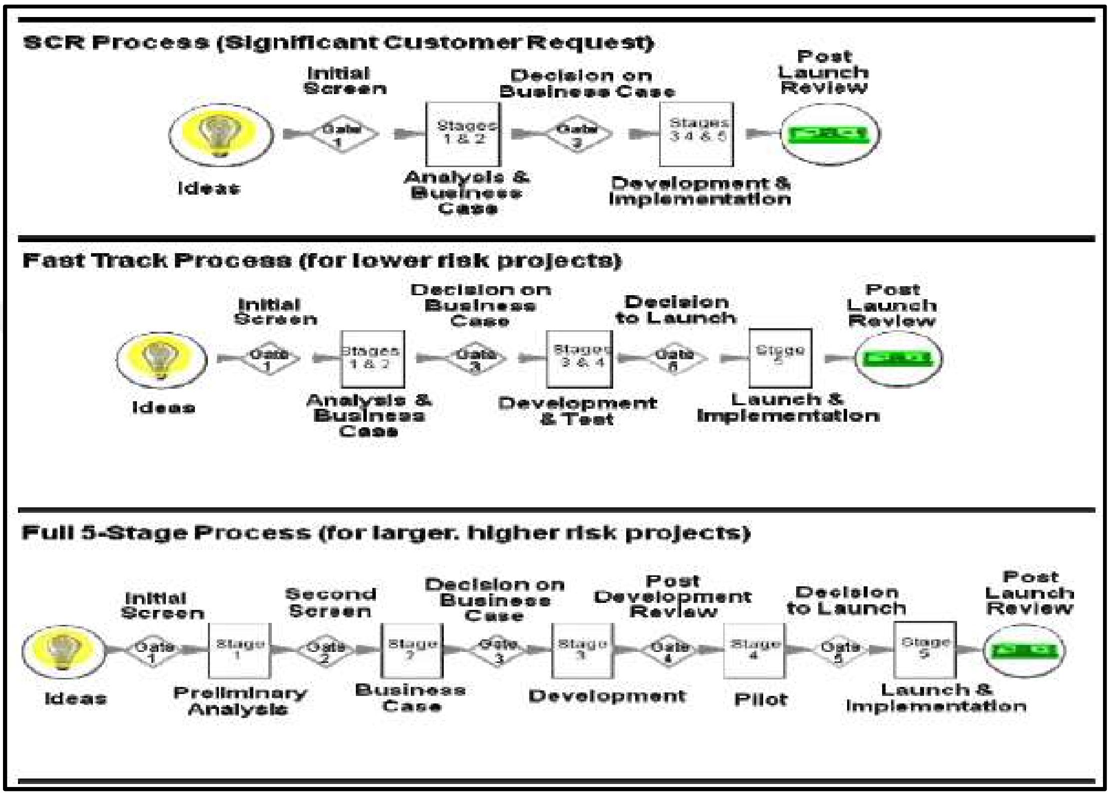


Figure 2.8 Optimized stage-gate models

After gate optimization, the authors profess the importance of integrating portfolio management into the stage-gate process. Since the stage-gate model is optimized to the each specific project, it is easier to make Go/Kill decisions for the projects. By the help of these decisions, the overall portfolio is improved in the way of selecting high value projects, achieving the right balance of the projects, achieving the right number of the projects and ensuring strategic alignment.

Broum et al. (2011) presents a new way of reducing the cost of innovation by integrating value analysis to the stage-gate process. Value analysis is a tool which aims to eliminate unnecessary costs in the project. The authors create a modified model of classical stage-gate process just shown in Figure 2.9 [18]:

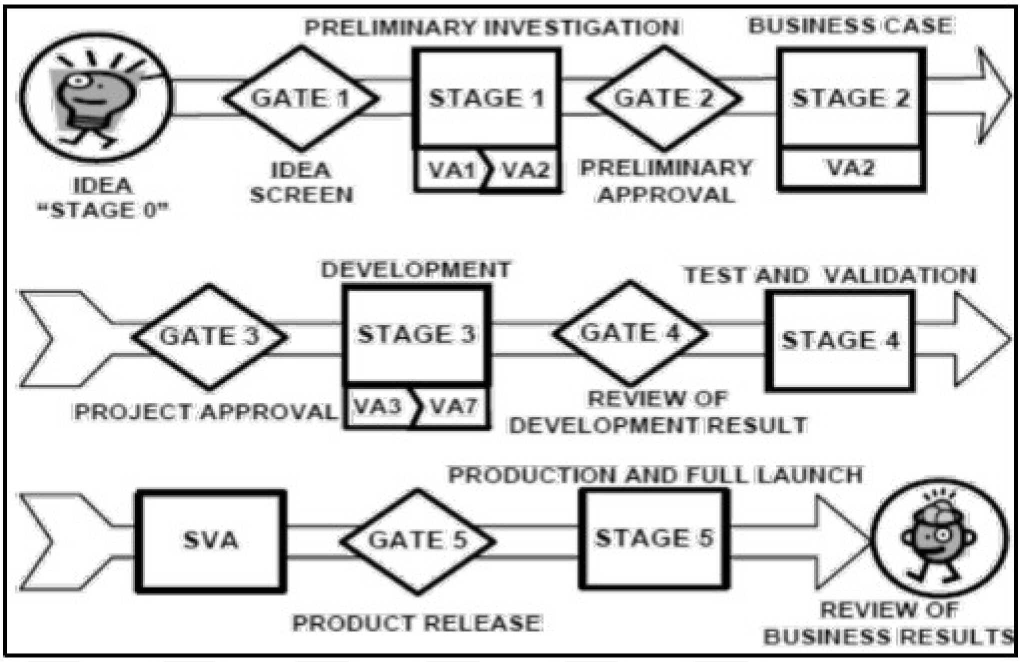


Figure 2.9 Combination of value analysis & stage-gate process

In the new model, it is obvious to tell that some steps of value analysis are implemented concurrently with Stage 1-2-3 of stage-gate process. Value analysis stage (SVA) is implemented after Stage-4 due to the fact that the critical problems are occurred during testing of prototypes and that gives a chance to project team to foreseen any possible problems at once. Therefore, the product value can be improved before launching product to the market by the help of SVA. As a summary, the combination of value analysis and stage gate process creates a new model that can reduce the costs of innovative product to the competitive level for the market.

CHAPTER III

POPULAR PROJECT MANAGEMENT METHODOLOGIES

3.1 Introduction

Regarding the level of the complexity of a project, companies develop different kinds of management methodologies which can be integrated with other processes or can be implemented as single-handed. The flexibility of a methodology is very critical since some unexpected problems can occur or changeable customer requests can appear in different phases of the project. In order to adapt new requests to the project or to overcome unexpected problems, companies should have a flexible project management method that can be compatible to the corporate culture.

Basically, project management methodologies cannot manage the projects on their own. Project manager is the one who manages a project by using different kinds of methodologies. At this point, senior management has a responsibility to a build a framework of company culture that saves project management methodology and put support behind it to reach the success for the project. If this framework is set up triumphantly, the benefits listed below can be gained [4]:

- *Faster "time to market" through better control of the project's scope*
- *Lower overall project risk*
- *Better decision-making process*
- *Greater customer satisfaction, which leads to increased business*
- *More time available for value-added efforts, rather than internal politics and internal competition*

For a successful implementation of a project management methodology, change management is a very important tool since it helps to create a flexible methodology. In a corporate, each department puts up resistance to change more or less. The resistance rate of each department is shared under 1.5.2 clause in this thesis. The research shows that it is necessary to integrate the project management methodology with corporate culture to create a perfect adaptation to changes and achieve the project against all the odds.

From customer's point of view, a project management methodology should be carried conviction. As the supplier company, which proceeds a project, tells the customer that there cannot be any scope change for the project, the customer should believe in the supplier since the supplier has trustable methodology. Kernzer (2010) shares an extreme example of the trust between a subcontractor company and its customer [8];

> *One automotive subcontractor carried the concept of trust to its extreme. The contractor invited the customers to attend the contractor's end - of - phase review meetings. This fostered extreme trust between the customer and the contractor. However, the customer was asked to leave during the last 15 minutes of the end - of - phase review meetings when project finances were being discussed.*

It is a very interesting decision to invite a customer to end-of-phase-review meetings because all important decisions are made for the next phase in this meeting and customer is directly a part of the final decisions. Therefore, the customer can be informed immediately about all the schedule issues and further work plans for the next phases. Of course, the financial issues are confidential for the subcontractor and thus the customer leaves the meeting at the last 15 minutes. This example demonstrates a high level of trust between a supplier and a customer.

During the evaluation of the project management, so many project management methodologies have been discovered and implemented to different kind of projects such as, software development, medicine, defense industry, new product development and aerospace industry. Since 1985 onwards some methodologies have been more popular than the others. Some of these methodologies were available to implement as single-handed; some have been integrated with different project management tools regarding project requirements and organizational culture. The popular methodologies will be explained with all details and which one is the closest to implement to a new product development (NPD) project will be discussed in this thesis. The most prominent methodologies are shown in Figure 3.1.

Figure 3.1 Project management methodologies

3.2 The Waterfall Methodology

This model is a traditional methodology which is generally used in software development projects. The model is developed by Dr. Winston Royce in 1970 as a tool to software development and he has published an article that presents this model [19]. The waterfall model takes its name from the analogy of water falling downward [9]. When the flow of the water is observed, there is no way to change the direction of flow to the opposite. In other words, the project phases are progressed without re-visiting the previous phase, generally. This methodology is fast but also so risky. The management of changes is really hard. If a fatal problem occurs at any phase of the project, that would cause to build all project phases from the beginning. The Figure 3.2 illustrates the waterfall model. The flow of water starts with system requirement phase and then goes on with software requirements. Analysis, program design and coding phases are development phases of the project. After the development is completed, the software is tested. If the results are positive and there are no bugs in the software, the project is ready to be sent to the customer. If there are some problems, the software is needed to be redesigned from the beginning. Hence, this method carries a high risk of project delay in case you face any problem in one of the steps.

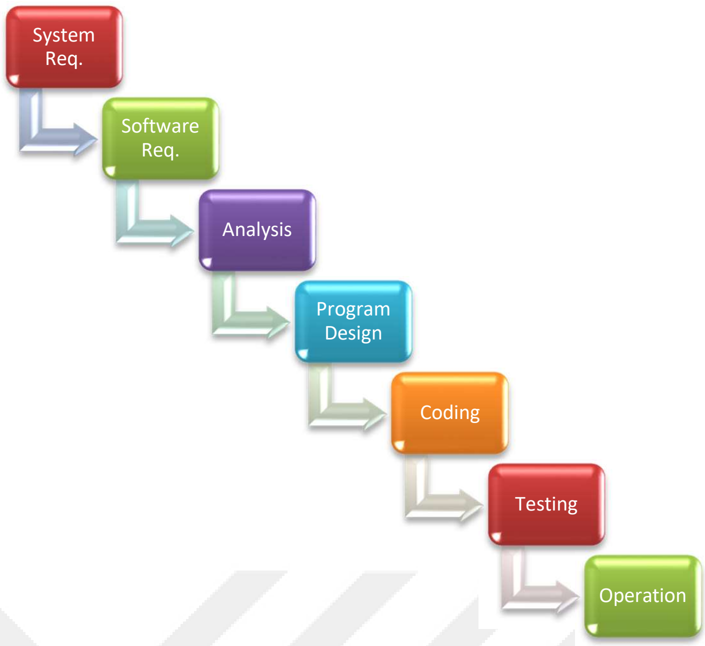


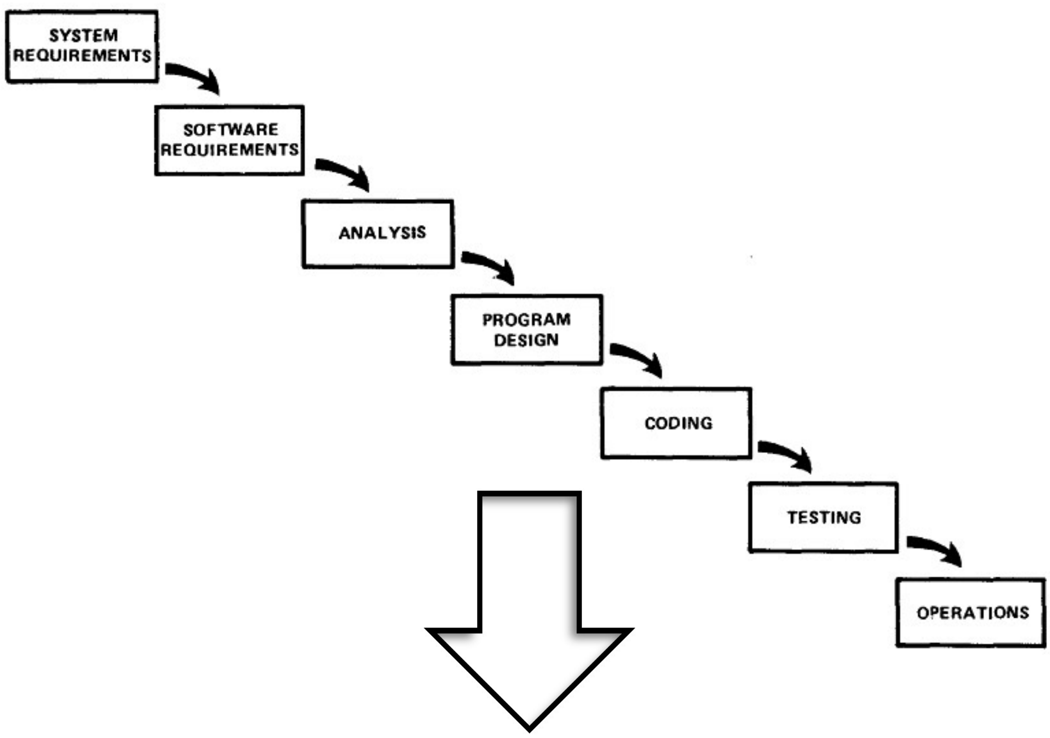
Figure 3.2 Waterfall model

Royce (1970) who develops the waterfall methodology also proposes an iterative model as an improvement proposal in the article [19]. In order to remove risks of development, he integrates five new steps to the waterfall model and therefore also the iterative model is improved.

- *Step 1: Preliminary Program Design:* This stage is added to the waterfall model in order to catch any possible problems in the software as earlier. Therefore, that stage gives a chance to programmer to recover the problems before final design.
- *Step 2: Design Documentation:* Documentation of each stage is very important for the software management. By this way, designer can present the completion percentage of the project to the customer or the project manager easily. The other good reason for documentation is to write what programmer thinks in a document and to make the idea gain value. Without documentation, that would be only an idea rising in the mind. Moreover, the documentation provides programmer to reduce mistake rate in software since it can be rechecked by different programmers. Finally, good documentation enables powerful redesign and updating of the phases in any case.

- *Step 3: Early Simulation:* This stage consists of doing a simulation of the software before the final product. The programmer starts with another preliminary design and then goes on with the operation phase. Therefore, the programmer has an opportunity of predicting some negative results beforehand.
- *Step 4: Plan, Control and Testing:* This stage proposes some ways to plan for testing;
  - Specialists can manage the testing of software better than program designer. It is only possible with good documentation.
  - Visual inspection is very important to detect errors in software.
  - Each logic path in the program is needed to be checked.
  - The critical decision should be made about the time and by whom the final checkout will be made.
- *Step 5: Customer Involvement:* This is a better way to make customer involved in the stages of software development. If the customer does not directly follow the situation of stages, that can cause some matters such as missing requirements, unexpected customer reaction to the results and so on.

After all steps are implemented to the waterfall model, an iterative model is created as a good software management. Figure 3.3 presents evolution of waterfall model;



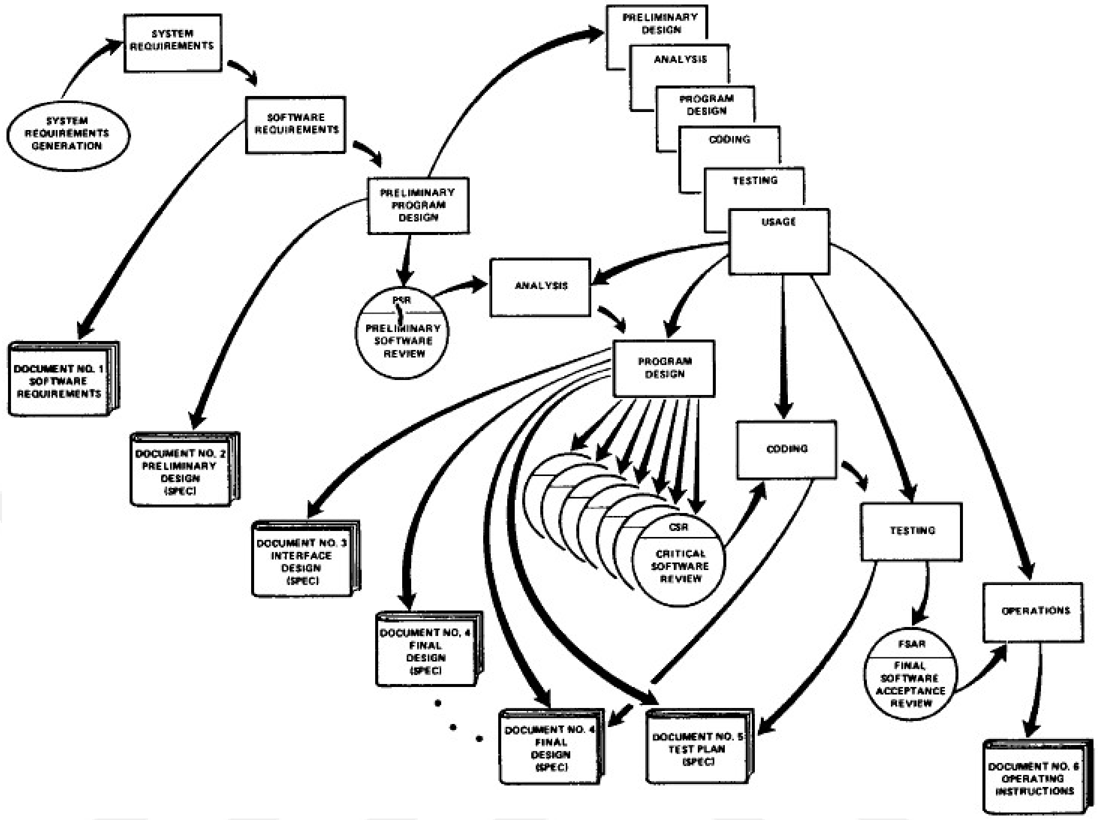


Figure 3.3 Evolution from waterfall model to iterative model

"PMO of the Year Award" is a very well-known awarding activity that is presented to the companies, which share their own project management improvements and best practices implemented in the company, with PMO (Project Management Office) through an essay and other documentation [8]. In 2009, Rockwell Automation Company has won this award by introducing its common product development process (CPD) to PMO. The company hired James C. Brown who is a PMO Director in order to implement new process. It has taken five years to adapt this new process to the company culture. The company moved from a "waterfall approach model to an agile approach". As an improvement, they observed that 20 or more paged reporting turned to 5 or less paged reporting to proceed and finalize a process. Additionally, the company increased the visibility of projects and resources within its own portfolio pool by the help of formal stage gate reviews. Hence, it was easier to make decision on going on/holding on/killing the project. As a result of leaving waterfall model and choosing a new process of agile methodology with formal stage gate reviews, Rockwell Automation finished more than 20 projects on time and under budget during five years and it has received PMO of the Year Award in 2009.

When the research data is combined with my point of view, waterfall methodology is not appropriate for NPD projects because the water may have to change its direction in case of a big uncertainty or a critical problem occurs during the project phases. If the water changes its direction, it is very hard to find the correct direction again. You need to implement all phases from the beginning and that causes more delay and waste of time in terms of project management process. In some applications, waterfall model is evolved into iterative models that allow phases to overlap between each other's and also implement some group of phases two or more times again to reduce risks. But in any case, waterfall model needs more documentation and it is very hard to track all phases because of inadequate feedback from phase reviews. That is why Rockwell Automation has left waterfall model and chosen an agile methodology. The research shows that waterfall methodology can be implemented to software projects with some improvements. For NPD projects, the methodologies which are more flexible and adaptable to changes are favorable.

3.3 The Agile Methodology

Agile methodology, which is one of the project management methodologies, is commonly used for software development projects. In many organizations, the main purpose is to create and deliver customer value effectively. Sanjiv Augustine who is the Director of the Lean-Agile Consulting Practice at CC Pace defines customer value as [20];

"Customer value is the right product for the right price at the right time."

Right product consists of all features that customer demands. The right price is a good deal that matches up with customer's prospect. The right time is when customer wants the product.

Sanjiv defines agile project management (APM) as;

"APM is the work of energizing, empowering, and enabling project teams to rapidly and reliably deliver business value by engaging customers and continuously learning and adapting to their changing needs and environments."

APM uses the agility for quick responses to the customer needs. In NPD projects, many of changes occur in project scope regarding changeable customer needs. In order to manage these changes, agile project management could be an alternative method but APM has been developed for software projects that can be managed as small iterative parts. Sanjiv presents key agile principles in "Agile Conference 2007" [21];

- ✓ *Focus on Customer Value*: Make your best to finalize project on time, to keep target price same, to give rapid responses for customer's needs.
- ✓ *Iterative & Incremental Delivery:* Send a software trial to the customer and get feedback. Then revise it until reaching to perfect one. Organize the software delivery into small increments, iteratively.
- ✓ *Intense Collaboration:* Ensure face-to-face communication between integrated teams.
- ✓ *Self-Organization:* Allow team members to be self-organized to fulfill a shared project vision.
- ✓ *Continuous Improvement:* Ensure that teams reflect, learn and adapt to change regarding customer needs; work plan should be revisable in agility.

Charvat (2003) reveals the industries that use agile methodologies and also commonly used agile methodologies in these industries [9];

- ➢ Extreme Programming (XP)
- ➢ Scrum
- ➢ Crystal Methodology
- ➢ Dynamic System Development Methodology (DSDM)
- ➢ Rapid Application Development (RAD)
- ➢ Adaptive Software Development
- ➢ Lean Development

- Feature-driven Development

Financial, IT, telecom, utilities, and many more service industries commonly use the agile methodologies mentioned above. These methodologies have been developed by years in an evolution. The evolution of APM demonstrates below [22];

Early 1990s

- Crystal Methods
- Lean Software Development
- Dynamic Software Development Method (DSDM)

Mid 1990s

- Feature Driven Development (FDD)
- Extreme Programming (XP)
- Adaptive Software Development & Scrum

The most prominent methodologies are elaborated by headlines and information below.

3.3.1 The Extreme Programming (XP) Methodology

XP is one of the popular agile methodologies. It has been developed by Kent Beck. It is based on iterations that include small releases, simple design, testing, and continuous integration [9]. In other words, programmer designs a prototype of real software and release to the customer. Regarding feedbacks coming back from customer, software is revised simply and tested again. Until the software meets the whole requirements of the customer, iterations will go on to be released.

XP consists of four values that the project teams should strictly follow. These values are demonstrated in Figure 3.4 [9];

Figure 3.4 Core values of XP

Extreme programming has four prominent practices which help XP to fit a complete development project and finalize it successfully [9];

- *Refactoring:* It is a restructuring operation that increases the quality and flexibility of the system without changing its behavior.
- *Testing:* Developers had better to write the tests before or after writing the codes of the system. Whenever the code is revised regarding customer needs, it should have been tested before releasing.
- *Pair Programming:* There are two developers in the same workstation that works simultaneously. This case helps to reduce time of releasing and also decrease errors and faults in the software code.
- *Use CRC (Class, Responsibility and Collaboration) Cards:* These cards contain standards which are used to teach the principles of object-oriented design to XP developers.

By the help of these practices, the customer will have a software code with more quality, less release time and without any errors at the end of the project.

3.3.2 The Scrum Methodology

Scrum is a lightweight methodology, developed by Ken Schwaber and Jeff Sutherland, which is used for agile software development. The main target of this methodology is to maximize project team's ability for giving agile responses to customer needs which change frequently [24].

With Scrum methodology, the project teams deliver the software within series of short time-boxes called "sprints" which includes a number of work items named as "backlog" [9]. Sprints finish nearly every 30 days and functional software is delivered to the customer. At the end of each sprint, customer can check what the current situation of the project is and has an opportunity to test a functional part of the software. Throughout one sprint, project team arranges daily project meetings called "Scrum". In Scrum meetings, team members are responsible to give answers to below questions [22];

Figure 3.5 Delivery of scrum meeting

After each meeting, deliverables are sent to the sprint cycle during a time period of sprint (15-30 days). After one sprint ends, an increment is shared with customer to be checked and tested. Then, a new backlog is defined and new sprint cycle starts. A summary of Scrum methodology progress is illustrated in Figure 3.6 [21]:

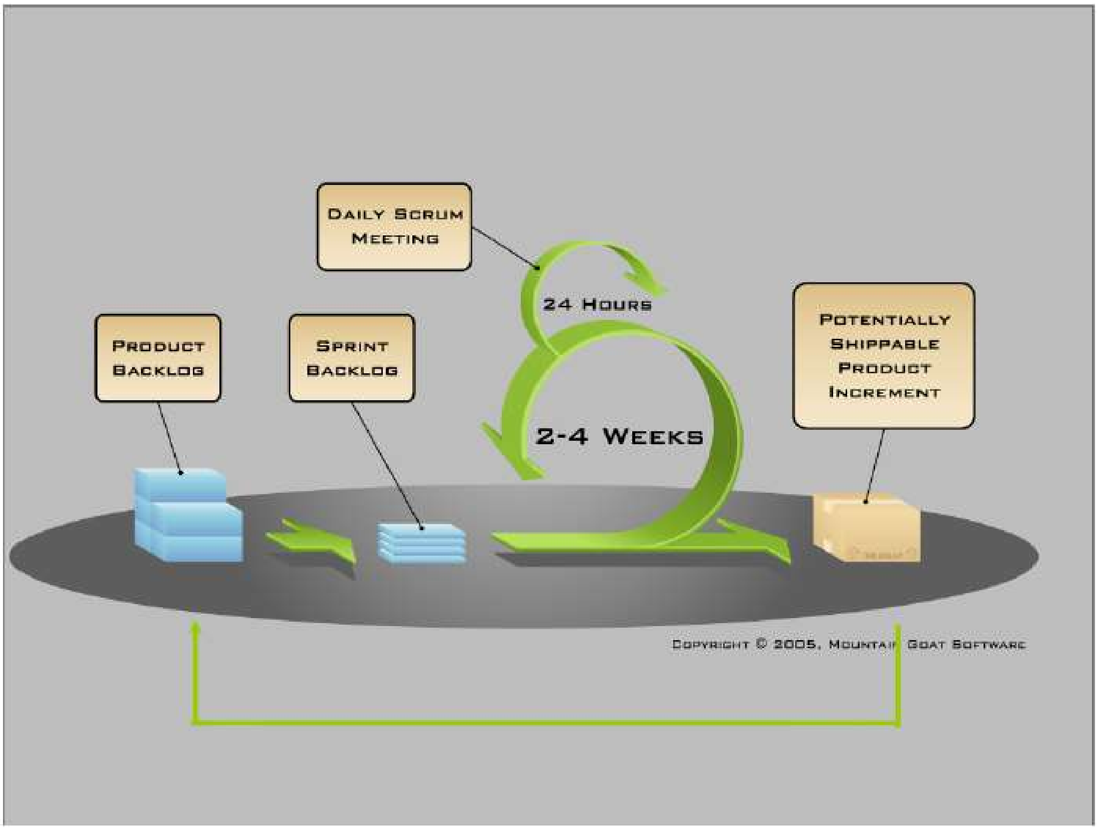


Figure 3.6 Scrum methodology progress

After all sprints end, product backlog will be completed and the whole software development is finished successfully.

3.3.3 The Crystal Methodologies

Crystal methodology has been developed by Alistair Cockburn. This methodology is a family of methodologies segmented into different color bands a crystal would emit (i.e., crystal clear, yellow, orange, maroon, blue and violet) [9]. All segments focuses on strong communications between team members for software development projects. Cockburn defines the Crystal as a family of human-powered, adaptive, ultralight, “stretch-to-fit” software development methodologies [23].

Human-powered means that the project can be achieved successfully by the help of people-centric approach.

Ultralight means that vast amount of documentation will not be allowed for a Crystal-family methodology without considering the project size and priorities.

Stretch-to-fit means that the project can be designed as a simple prototype of all system. Then, it can be grown until reaching to final project size. In other words, stretching a small size of software codes to the final size is more logical than designing full software codes and then cutting away to reduce it for final size.

Charvat shares two main principles of Crystal as [9];

- Team members should be placed in same location to gain an improved development and creativity.
- Face to face communications should be actualized during the project life cycle.

3.3.4 The Dynamic Systems Development Methodology (DSDM)

DSDM is a kind of the agile project management method that is generally used as a software development method. It is based on Rapid Application Development (RAD) and developed in the United Kingdom. Different from other development methodologies, time, cost and resources are fixed; the final product can be variable in DSDM. The main goal is speed by saving the quality of the final product also [9].

DSDM is based on an iterative development model that gives quick responses to changing customer requirements. Main target of DSDM is to implement the business requirements on time, within project budget and by saving quality. Within the iterative approach, a DSDM project is structured into three distinct phases [24]:

- *Pre-project phase:* This phase contains a preliminary work of the project in which the initial definition of the business problem, budget and resource, plans for feasibility study and a go/kill decision.

- *Project life cycle phase:* This phase includes feasibility study and all sequential and iterative stages which will be implemented throughout project life cycle. Project phases are proceeded in the scope of a project plan.
- *Post-project phase:* This phase is proceeded to ensure the ongoing effective and efficient operation of the delivered system by the help of activities such as maintenance, continuous improvements and software revisions.

The Figure 3.7 illustrates a graphical overview of the DSDM phases and stages. During project life-cycle phase, there are feasibility and business study sequential stages in addition to functional model, design & build and implementation iteration stages. By taking into consideration the feasibility report, business area is defined and the requirements of the customer are prioritized. Then, system framework is defined within a development plan. Lastly, risk log, which is delivered by feasibility report to the business study stage, is updated. In the functional model iteration stage, functional prototypes are developed and an implementation plan is prepared. Lastly, risk log is revised again. Tests are performed to ensure the software satisfies the customer business requirements in the design & build stage. In the implementation stage, the tested system is installed in the customers' working environment. Users, operators and staff are trained as to implemented software. Lastly, additional development requirements for future iterations are specified.

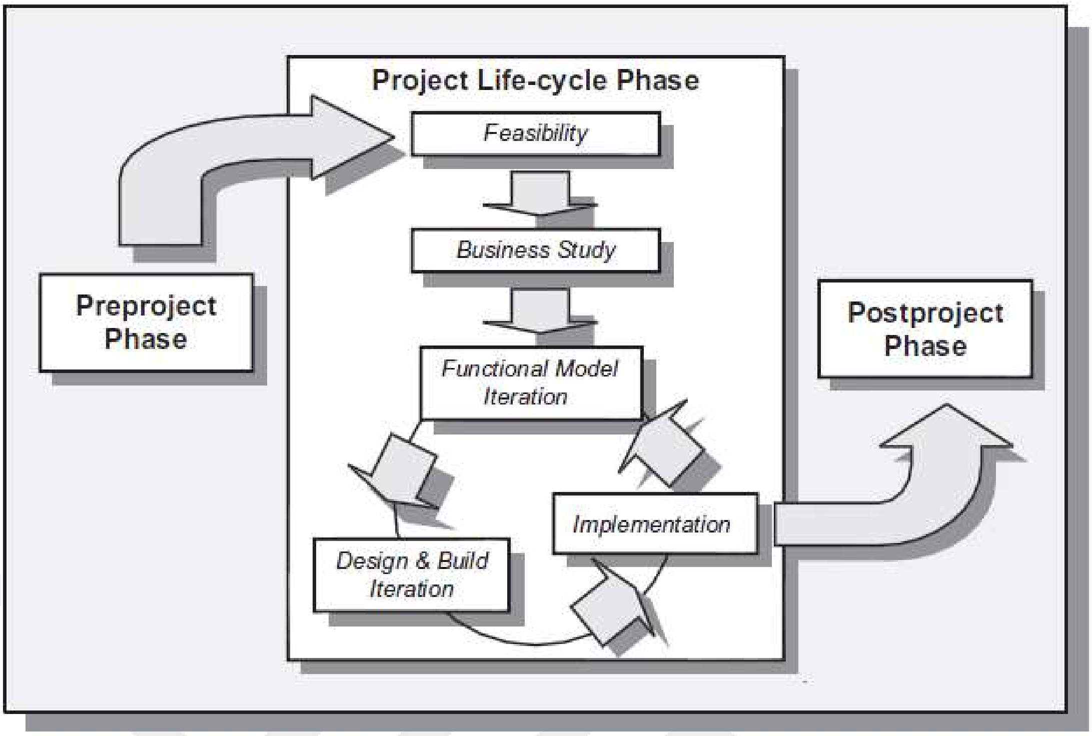


Figure 3.7 DSDM phases

3.3.5 The Rapid Applications Development (RAD) Methodology

Rapid application development is a methodology which is put forward by James Martin in 1980's. This methodology gives an approach as an enhancement to the waterfall methodology developed by Winston Royce [19]. RAD is common for software development projects.

Different from traditional methodologies, RAD includes short iterative development cycles, in which a simple working prototype of the whole software is implemented, instead of classical analysis, design, development and test phases. Figure 3.8 is clearly illustrates the difference between RAD and traditional developments [9]:

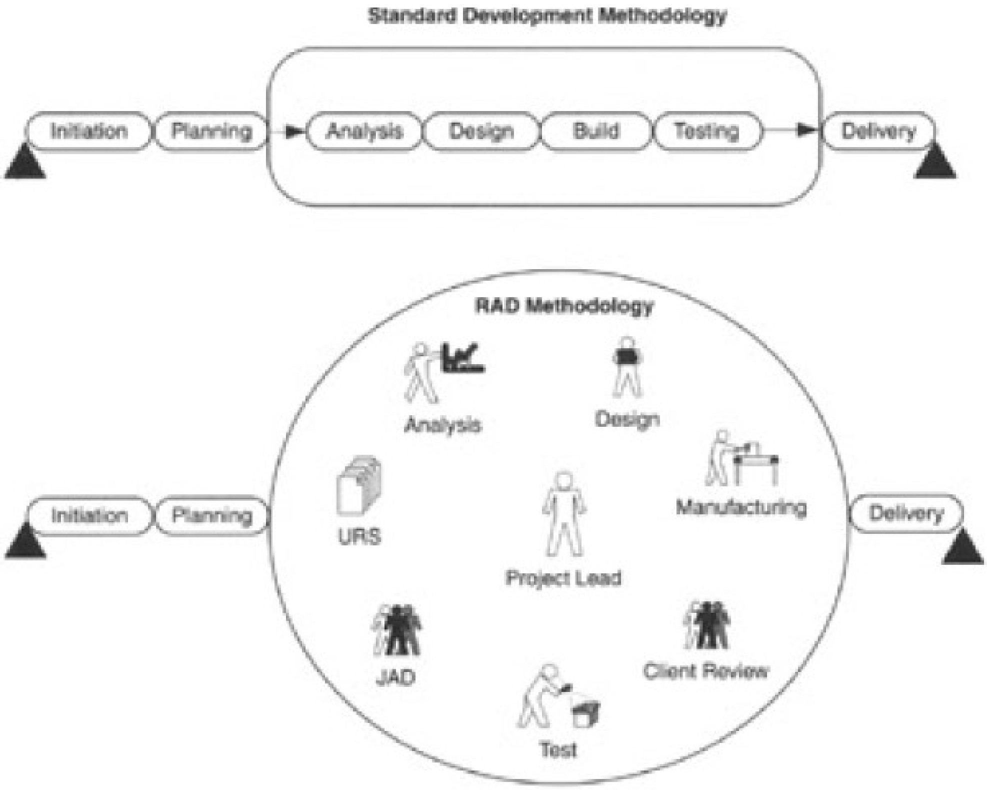


Figure 3.8 RAD Methodology

From the figure, it is simple to say that the project phases are not performed sequentially in RAD; they are performed as concurrently. The phases are extremely dynamic and teams are adaptive to dynamic changes of customer needs.

Basically, the key goals of RAD are [24];

- High quality systems
- Fast development and delivery
- Low costs

RAD allows customers to be involved in the development phases. That is an important step to manage customer needs. Hence, project manager can shape the future of the project regarding new requirements of the customer. Nobody will face a surprise at the end.

RAD has four prominent features that distinguish it from traditional methodologies [24];

- *RAD's iterative approach* gives an opportunity to catch any possible defects by testing the software in earlier steps of the project. The software would be improved via iterations. Delivery time would be shorter than waterfall projects.
- *Closer customer involvement* helps the project manager and his/her team to test if the software meets the customer needs or not and the customer directly make some suggestions to developers to be able to cover all specifications agreed on at the beginning.
- *Accepting that requirements would no longer be set in stone* allows that changes could be managed effectively throughout the development to ensure the delivered software would meet the customer requirements.
- *Tighter project management* of development priorities, costs and timescales kept project progress on track and save the development under control.

As agile methodologies are compared with waterfall methodology, it seems that agile methods are much more flexible and adaptive to customer requirements that change rapidly. Agile methodologies are generally used for software development projects in the market as a better way than waterfall model. But also this methodology is not adaptable to all phases of NPD projects directly. Maybe, if one of the development phases of NPD project is software development of the final product, then a suitable agile methodology can be implemented only to that phase.

In terms of global project management excellence, six companies namely, "IBM, Computer Associates, Microsoft, Deloitte, Johnson Controls and Siemens" are prominent ones [8]. Global project management excellence refers to specialized best practices and features of globalized project management. IBM has developed the Worldwide Project Management Method (WWPMM) which presents the best project management practices for many of projects. This methodology has been created based on PMI *PMBOK® Guide* as adaptive to IBM company environment. IBM also uses “agile project management” approach to develop software and IT solutions within WWPMM.

3.4 The Six Sigma Methodology

Six Sigma is a process improvement methodology that is based on quality management. Motorola reinforced this methodology in the mid-eighties. This methodology, also known is DMAIC, is utilized for process improvement projects. DMAIC can be detailed as [26];

- ✓ **D**efine the problem and customer requirements
- ✓ **M**easure defects and process operations
- ✓ **A**nalyze feedback data and find out the root causes of the problem
- ✓ **I**mprove the process continuously to remove the root causes of defects
- ✓ **C**ontrol the process to ensure that defects don’t occur again.

The main goal of Six Sigma is to reduce defects and process variance of the products. Lean manufacturing is also a process improvement approach that is linked to Six Sigma. Lean has been derived from the Toyota Production System (TPS). Both approaches defend to reduce defects and improve total quality of the product. The main target of lean manufacturing is to remove wastes and reduce the cycle times and costs. The most common tools, which lean methodology utilizes during implementation of lean to the process, are listed below [4, 26]:

- ➢ *Kaizen Events:* Kai (take part) and Zen (make good) is a well-known word in Japanese. Kaizen is an action-operated approach to process improvement. That includes continuous improvement actions on the current processes.
- ➢ *Five Whys:* This method includes consecutive questions until reaching the root cause of process defects and waste throughout the progress of the project. Of

course, five is a symbolic number; it may be possible to find the root cause with only two questions or even very hard to find it with ten questions.

- *Five S*: This method is occurred by the first letters of the following words in Japanese; seiri, seiton, seiso, seiketsu, and shitsuke. They bring tidiness (seiri), and cleanliness (seiso) to operations and keeps self-discipline (shitsuke) needed to systematize (seiton) and standardize (seiketsu) the processes.
- *Poka-Yoke:* That is another Japanese word occurred by combining Yokeru (to avoid) and Poka (inadvertent errors). Poka-Yoke advocates a system with zero defects. Therefore, this methodology consists of process designs that make it impossible to do something wrong even if it is the first time.
- *Pull Scheduling:* Within this method, the internal supplier does not save high rate of stock in the warehouse. Until an internal or external customer needs a part, supplier does not produce anything. This practice contributes to "just in time" production.

As Six Sigma and lean manufacturing is combined, it is called as "Lean Six Sigma (LSS)". That is a project management methodology which reduces defects and removes wastes that affect the cycle times and costs of a project. Companies generally implement this combined methodology to process improvement projects.

Rayna Ilieva has presented "Lean Six Sigma" methodology in PM Day Bulgaria 2013. The simple illustration of Lean Six Sigma is presented in Figure 3.9 [25];

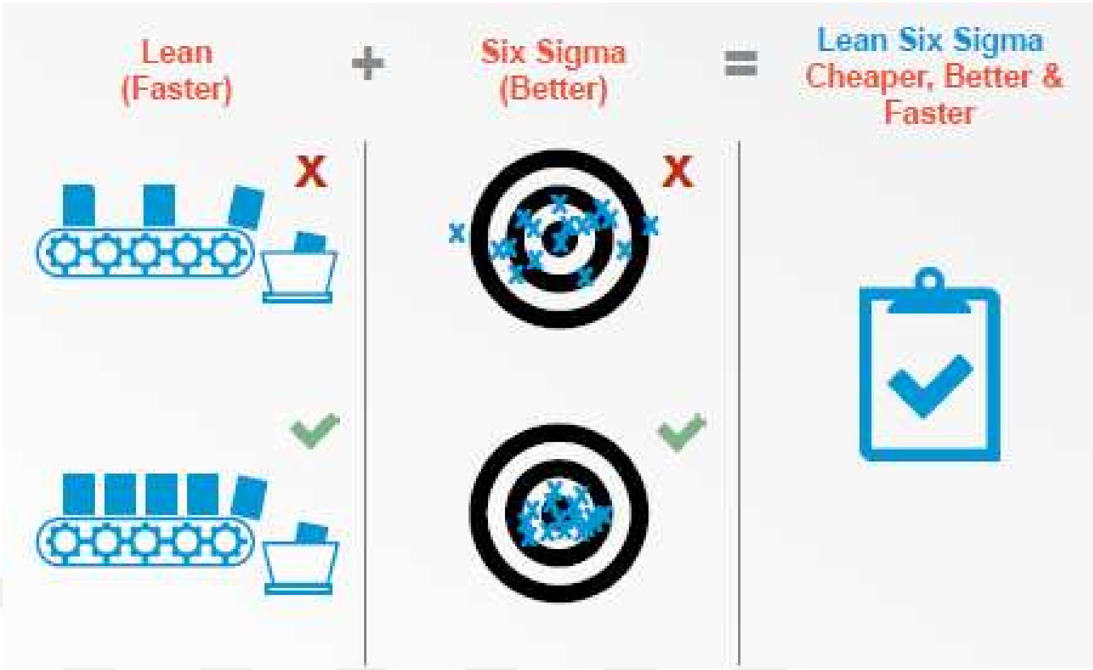


Figure 3.9 Lean six sigma (LSS) methodology

As seen in the figure, lean methodology gains faster process in production lines and Six Sigma methodology gains the lowest level of variance on quality. When these methodologies are combined as Lean Six Sigma (LSS), the process becomes cheaper, better and faster. As summary, LSS focuses on improving quality, reducing waste and increasing speed.

PMBOK® Guide defines the project management tools as "concept, design, planning, execution and closure. LSS gains a different approach to these tools by DMAIC methodology. The comparison of these tools is shared in Figure 3.10 [25]. By this approach, LSS proposes more analytic progress to the processes and advocates continuous improvement. LSS framework always works on increasing quality, making continuous improvement and reducing wastes. However, improvement projects are not managed just as real projects since there is no PM standard while implementing new improvements to the process.

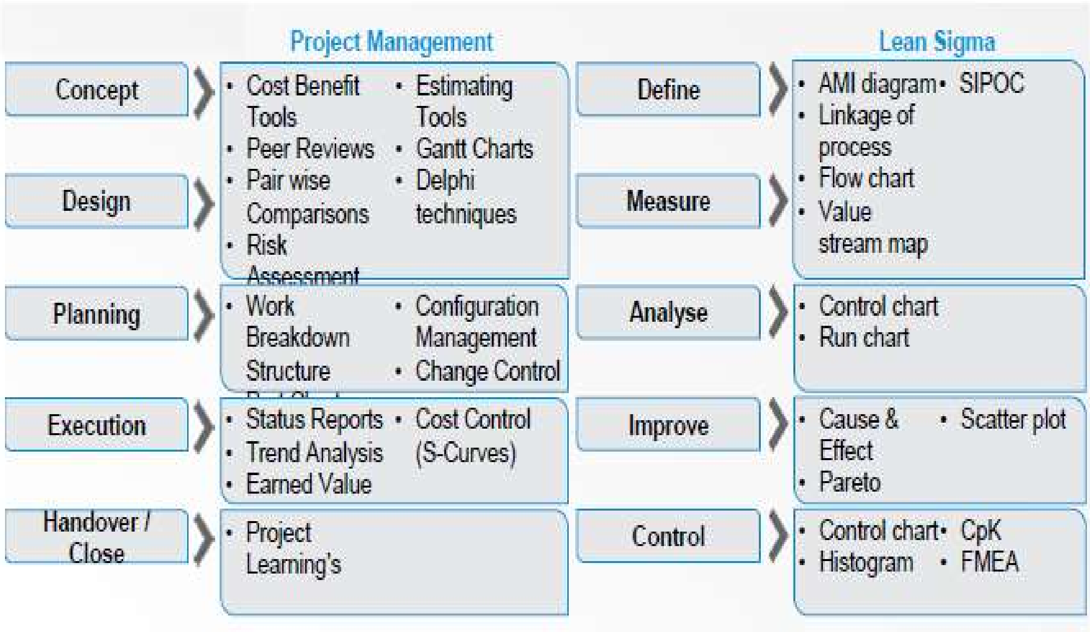


Figure 3.10 PM vs. LSS in terms of tools

A good model of project management methodology is designed when LSS is combined with project management (PM). Generally, manufacturing-oriented Six Sigma fails because of lack of project management. Six Sigma needs the support of project management practices in order to manage projects as projects. For planning, scheduling and execution of the projects, Six Sigma should apply project management principles. Six Sigma does not work only in manufacturing; it can be used also for other applications. In GE's 1997 annual report, CEO Jack Welch proudly states that [8];

"Six Sigma focuses on moving every process that touches our customers — every product and service (emphasis added) — toward near - perfect quality."

In other words, combination of LSS and PM will be a methodology which can be implemented not only to manufacturing-based projects, but also to other type of projects. In 2002, DTE energy has developed an enterprise project management methodology called as "4 - Gate/9 - Step project management model" in order to improve their current Lean Six Sigma methodology. In Figure 3.11 this project management model is presented in details [8];

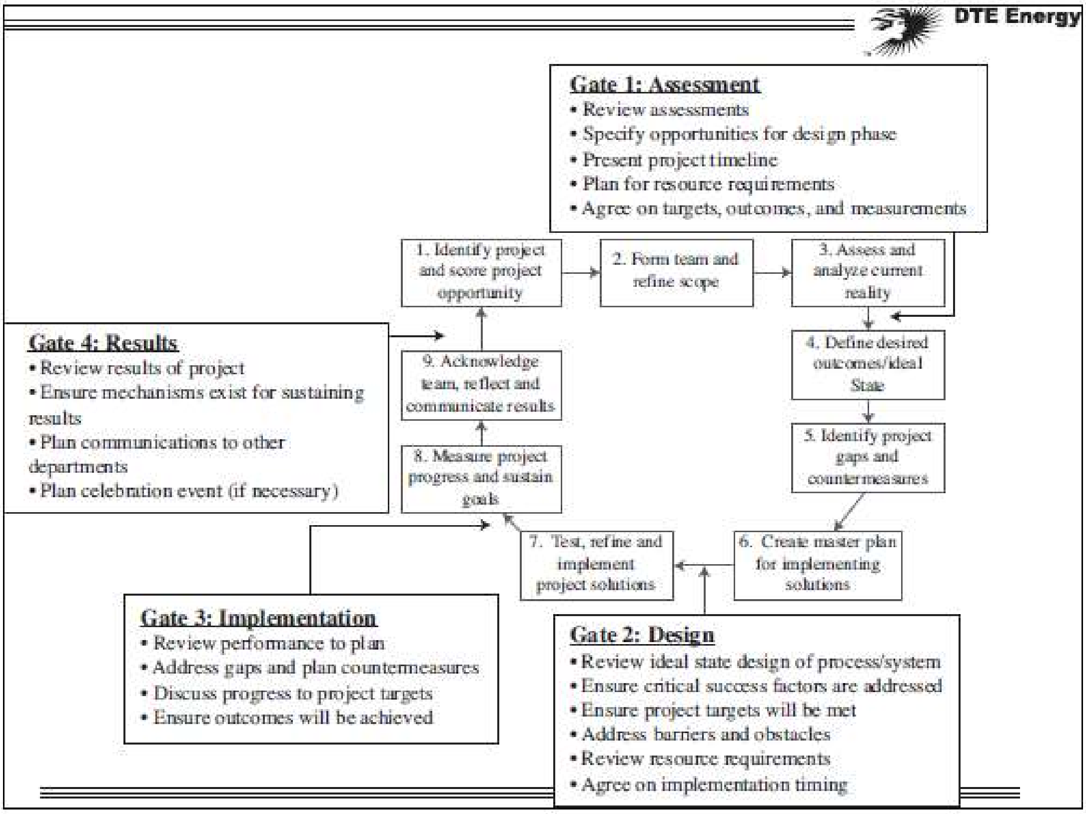


Figure 3.11 4 - gate/9 - step project management model

In steps 1-3, project scope is defined, teams are formed and current reality is reviewed. All Black Belt certified projects must achieve at least $ 250,000 in savings or have a significant impact in safety or customer service. After completion of these steps, Champion signs Gate 1 review form.

In steps 4-6, project team defines desired outcomes and ideal state. Then, project gaps and countermeasures are identified by using the failure mode and effect analysis (FMEA). In order to implement solutions, a master plan is prepared. The team measures both input and output metrics and measures the success of the project in terms of improvement on these metrics. Champion signs Gate 2 review form.

In steps 7, project team progress its master plan to test and implement the project solutions. Champion signs Gate 3 review form after discussing gaps, countermeasure plans and projects targets.

In steps 8-9, project team measure progress and sustain goals. Moreover, the team reflects on the results and discusses the project situation in details. Before the sponsor signs off at Gate 4, must have been reached to project targets. If not, the team returns to Gate-2.

DTE Energy has saved over $40 million in 2003 and over $100 million in 2004 by using 4 - Gate/9 - Step project management methodology. Why? Because, DTE Energy has improved its LSS methodology as it is combined with project management. It seems that DTE Energy was inspired from “Stage-Gate” project management methodology but not directly implemented its all principles to their LSS model.

Convex Corporation implemented a Six Sigma project that consists of changing internal reporting system [8]. Instead of utilizing bulky status reports, they intend to replace it with color-coded reporting system using the company intranet. Color codes were showing the potential importance of the reports. Project management office (PMO) of the company used the below data for analysis;

- The cost of executive level: $240/hr
- Number of project review meeting per project: 8
- Meeting duration: 2 hours
- Number of executives per meeting: 5
- Number of projects requiring executive review: 20

With a simply calculation, total cost of executives;

(8 meetings) x (2 hours) x (5 executives) x ($240/hr) x (20 projects) = $384.000

In order to reduce cost, Convex improved the reporting system. Firstly, Convex hired a system programmer who works 40 hours per week and costs $100/hr. The programmer set up the color-coded reporting system to the intranet for four weeks. Totally, the cost was $16.000. After six months, the number of meetings had been reduced to 5 from 8 and the duration was 30 minutes instead of 2 hours since the executives only focused on important color codes from intranet. After one year, the total cost of meetings was about $60.000. In other words, Convex has saved

$324.000 per year under favor of only one investment of $16.000. How one small investment (input) can create a big gain (output) is shown graphically in Figure 3.12:

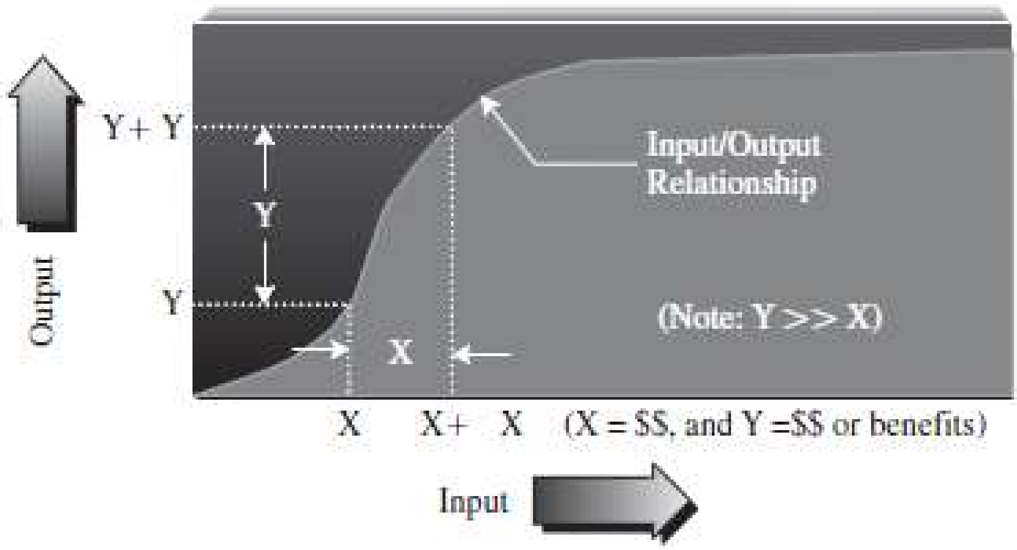


Figure 3.12 Six sigma quantitative evaluation

The research verifies that Six Sigma is only a process improvement framework as single-handed. When Six Sigma combines with Lean manufacturing, LSS is occurred. LSS focuses on rapidly improving quality, reducing waste and increasing speed of the process. But LSS methodology generally fails if project management does not support it. Finally, when LSS includes project management principles, the Six Sigma projects are managed nearly perfectly. On the other hand, LSS methodology is preferred for process improvement projects. For new product development (NPD) projects, LSS is not appropriate briefly. After an NPD project is finalized, Six Sigma can give support in order to improve some phases or processes throughout the project. But, Six Sigma methodology cannot build whole structure of NPD projects.

3.5 The Stage-Gate Methodology

Stage-Gate methodology was occurred firstly in the mid-1980s. From that time, it has been used by so many companies which drive new products to the market within competition. Of course, this methodology gains new names depending on different company cultures. Each company modifies Stage-Gate process by combining with their own project management methodology system. Nowadays, next-generation Stage-Gate systems are more flexible, adaptive and scalable [27]. Before going through next-generation Stage-Gate methodology, traditional Stage-Gate system will be presented, basically.

3.5.1 What is Stage-Gate Model?

Stage-Gate model is a project management methodology that is used for new product development projects to improve effectiveness and efficiency [29]. Basically, it is occurred by "a series of stages" in which the project team conducts the work items of the project and "gates" in which project team makes Go/Kill decisions to continue the project or eliminate it from the total portfolio. Typical Stage-Gate system is illustrated in Figure 3.13 [28];

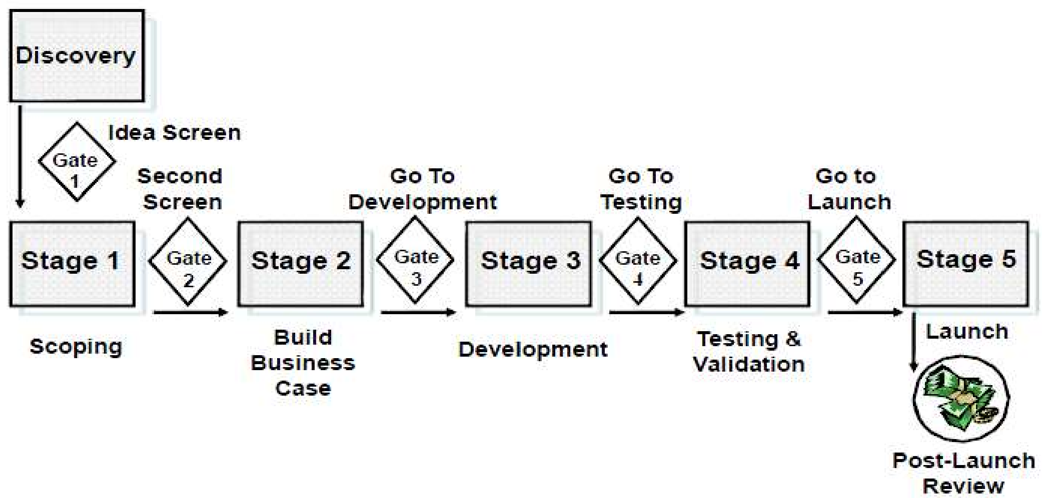


Figure 3.13 A typical stage-gate system

The Stages

Stages include "activities" in which project team gathers information; "integrated analysis" in which the activities are analyzed and "deliverables" in which project team conducts the results of integrated analysis as an input to the next gate. Each stage is cross-functional; in other words, there is no any stage that belongs to R&D department or Sales department. Activities of all departments (R&D, Production, Marketing, Purchasing and etc…) are managed concurrently within one stage. Even if each stage costs more than previous one, uncertainties are decreased. General flow of stages is shown in Figure 3.14 [29];

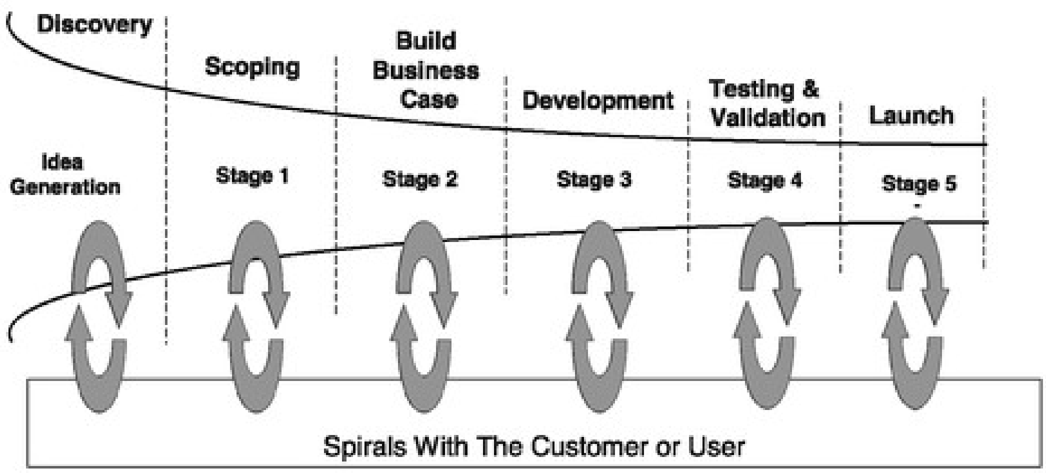


Figure 3.14 General flow of stages in the idea-to-launch stage-gate system

- *Discovery - Idea Generation:* This stage includes pre-works to discover and generate new ideas. Many activities can be part of the Discovery stage in order to stimulate the creation of great new-product ideas.
- *Stage-1 - Scoping:* Stage-1 consist of a quick investigation on the project scope. For this stage, ten to twenty person-days' work effort is needed and it takes one month maximally. A preliminary market assessment and technical assessment are implemented. In conclusion, both financial and business analyses are presented as deliverables to Gate 2.

- *Stage-2 - Build Business Case:* Stage-2 includes a very detailed investigation on technical and marketing. Product specifications are clarified and attractiveness of the project is verified before high level of spending. Market studies are performed in order to specify customer's requirements and preferences and hence that is to define winning new product. Also there is one more market activity; new product is presented to potential customers and their reaction to the new product is observed.

  Project team also focuses on very detailed technical and manufacturing review at the Stage-2. For technical side, customer's needs are blended in technically and economically feasible conceptual solution. Some prototypes are designed and tested in laboratory. For manufacturing side, manufacturability, supply chain, manufacture cost and needed investment are researched.

  Finally, a detailed business and financial analysis (cash flow approach and sensitivity analysis) are involved in Business Case as deliverables from Stage-2. Extensive project plan is developed.
- *Stage-3 - Development:* Detailed design and development of new product, operations and production process are performed at Stage-3. The deliverable at the end of Stage 3 is a partially tested prototype of the product. There are the "build-test-feedback-revise spirals" in which the prototypes are designed and taken to the customer for assessment and feedback. On the other hand, marketing and operations activities also proceed in parallel with technical issues. In other words, market launch plans, and production or operations plans are developed. An updated financial analysis is prepared, while regulatory, legal, and patent issues are resolved.
- *Stage-4 - Testing & Validation:* Tests of new product are performed in laboratory and field at Stage-4. The activities, implemented for validation of new product at this stage, are listed below;
    - Laboratory tests that simulate in-house conditions
    - Field tests
    - Pilot production and operations
    - Marketing test and trial sell to gauge customer reaction and determine revenues

- Revised business and financial analysis to review new and more accurate revenue and cost data

An important note; in case Stage-4 gives negative results, project team can return to Stage-3.

- *Stage-5 - Launch:* This final stage involves implementation of both the Market Launch Plan and the Operations Plan. Production equipment is supplied and installed entirely. Sub-parts are supplied and production starts. Immediately after, selling begins regarding commercial agreements with customers. Finally, another winning new product is being launched successfully.

The Gates

Gates are Go/Hold/Recycle/Kill decision points for the project. Deliverables come from the preceding stage and they are reviewed by the gatekeepers to make a final decision. Through the process of decision making, gates consist of three parameters; “deliverables”, “decision criteria” and “defined outputs”.

- *Deliverables:* These are the results of completed activities which are carried out from the previous stage by project team.
- *Decision Criteria:* It is a kind of check list which is used in order to be sure if the ongoing project still meets the requirements and consist of desirable features.
- *Defined Outputs:* According to the feedback from decision criteria, final decision of Go/Hold/Recycle/Kill is made. The ongoing project is prioritized among the other projects regarding the final decision. The final decision, action plan for the next gate and a date for the next gate are outputs from the gate. Final decisions are made by gatekeepers who are senior managers from different functions. They also provide resources to the project manager and project team throughout the project.

General flow of gates during a project is shown in Figure 3.15 [29];

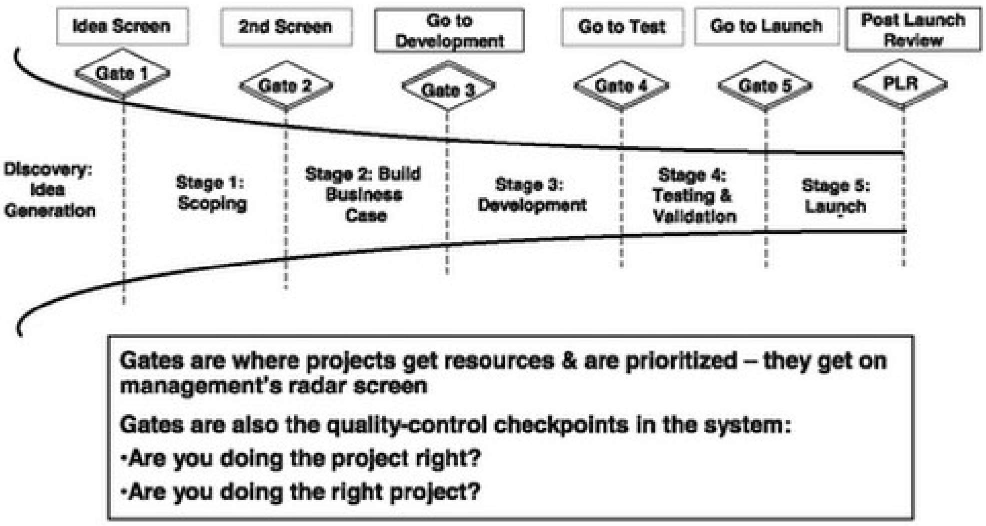


Figure 3.15 General flow of stages in the idea-to-launch stage-gate system

- *Gate-1 - Idea Screen:* It is the first decision that clarifies if the project starts or not. Project feasibility, market attractiveness, product advantage, magnitude of opportunity and compatibility to company policies are important criteria which help to make decision.

Exxon Chemical Company has implemented PIP (Product Innovation Process) system which is a kind of decision criteria for the first gate [29];

Strategic fit: Does the proposal fit within a market or technology area defined by the business as an area of strategic focus?

Market attractiveness: Are the market size, growth, and opportunity attractive?

Technical feasibility: Is there a reasonable likelihood that the product can be developed and produced?

Killer variables: Do any known killer variables exist (e.g., obsolescence, environmental issues, legislative actions)?

The gatekeepers are both from technical and marketing people. If the answers to all the questions are “Yes”, the project starts. If not, the project is killed.

- *Gate 2- 2nd Screen:* Gate-2 is similar to Gate-1 but as a difference, project is reviewed again with new information coming from Stage-1. The financial return is assessed at Gate 2, but only by a quick and simple financial calculation. Just as Gate-1, this gate also includes must-meet and should-meet decision criteria. Must-meet items must be answered with “Yes” for Go decision. Should-meet items are rated via point-count system.
- *Gate 3 - Go to Development:* Some firms call this gate as “Money Gate” since Gate-3 is the last gate before starting high level of spending. Beginning from the development stage, project cost will increasingly reach to higher levels. Generally, “Kill” decision is made at Gate 1, 2 or 3. After Gate-3, only a few projects are killed. Results of activities delivered from Stage-2 are evaluated in this Gate. Structure of decision criteria is same as Gate-2. If the decision is “Go”, the Development Plan and the Preliminary Operations and Marketing Plans are reviewed and approved at this gate. All members of the project team and the project leader are assigned. Resources are formally identified.
- *Gate 4 - Go to Testing:* Deliverables from development stage is evaluated and checked if developed product meets all requirements and desirable features or not. At Gate 4, financial analysis is deeply made based on new and more accurate data. If the decision is “Go”, Test and Validation Plan is approved as an output for the next stage. Moreover, detailed Operations and Marketing Plan is evaluated against the likelihood of future execution.
- *Gate 5 - Go to Launch:* This is the final gate prior to starting product launch. However, there is still a possibility of “Kill” decision. Gate 5 focuses on the quality of activities in Stage 4. In order to pass this gate, decision criteria consist of;
    - Test results must be positive
    - Financial return must be in expected level
    - The launch and operations plans must remain solid
    - Readiness for the launch in terms of commercial factors must be checked

Operations and Marketing Plans are reviewed and approved for the last time. Even in some companies, Product Life Cycle Plan (from launch phase to product exit) is reviewed.

- *Post-Launch Review:* After the new product turns to regular product in production line (it takes six to eighteen months), performance of project and the product is reviewed. Costs, revenues, profits are evaluated. What has been learnt and what can be improved in the next project are under discussion in the company. Project team and leader remain responsible for the success of the project through this post-launch period.

  Emerson Electric's NPD Stage-Gate system consists of two post-launch reviews. First review is one to two month after launch, which includes corrective actions and evaluation of team performance. Second review is twelve to twenty-four months after launch, which gauges the quality of NPD process by comparison of actual versus promised results and terminate the project [29].

3.5.2 Stage-Gate Methodology for New Product Development (NPD)

Stage-Gate system is generally preferred for NPD projects in the market. Stage-Gate and project management are used together and a project management methodology occurs. Project management methods are applied within the stages of the Stage-Gate process. In this clause, implementation of this process in different companies would be presented.

As explained in the Clause 2.2, Rockwell Automation Company has won PMO of the Year Winner Award at 2009. The company has turned from waterfall methodology to Common Product Development (CPD) Stage-Gate Process which is illustrated in Figure 3.16 [8]. Investment proposals are reviewed and the projects are prioritized throughout portfolio management process. In project management process, the prioritized projects are managed through five stages and five gates.

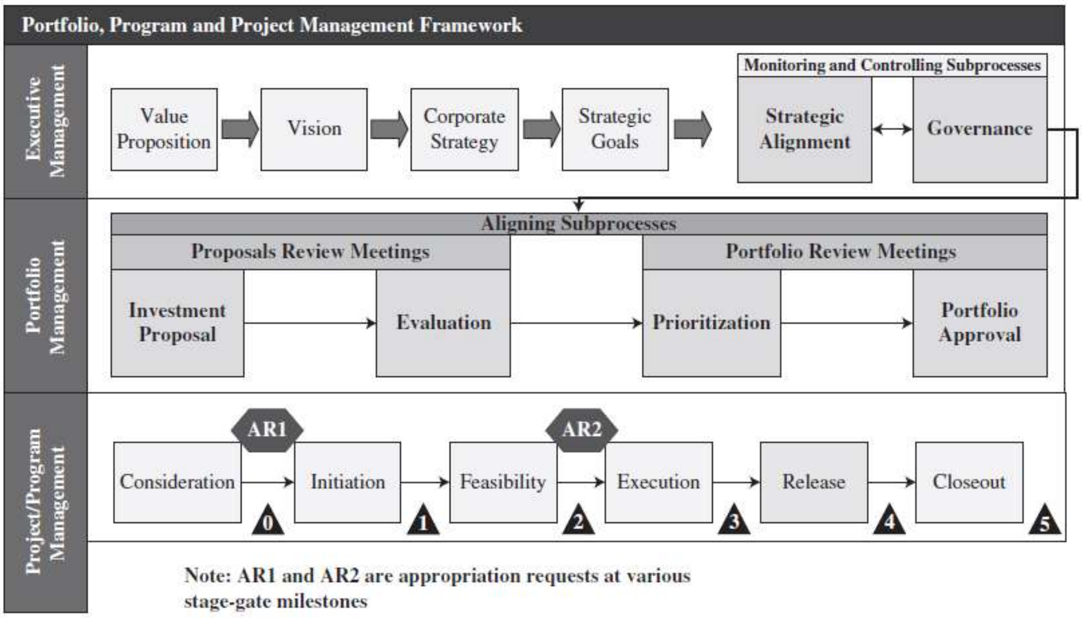


Figure 3.16 Common product development (CPD) stage-gate process

Corning Glass has always been a world-leading innovator in glass process; recently with fiber optics and flat-panel display glass. The company is used a version of Stage-Gate methodology since early 1990s for driving mew products to the market. All new product developments, product improvements and new manufacturing processes have been made via Stage-Gate over the years [29].

Emerson Electric's NPD 2.0 is latest version of its stage-and-gate system implemented in this company. The NPD team utilizes Phase Gate approach which is derived from Stage-Gate method. Randall Ledford, senior vice president says that Phase Gate method encourages Emerson's excellent executing and process [29].

P&G's SIMPL new-product process is a kind of Stage-Gate system also. It was generated in the early 1990s and nowadays it is in third generation. This method has been a key methodology to the other firms in order to introduce new products to the market [29]. The basic demonstration of SIMPL methodology is presented in Figure 3.17 [29]:

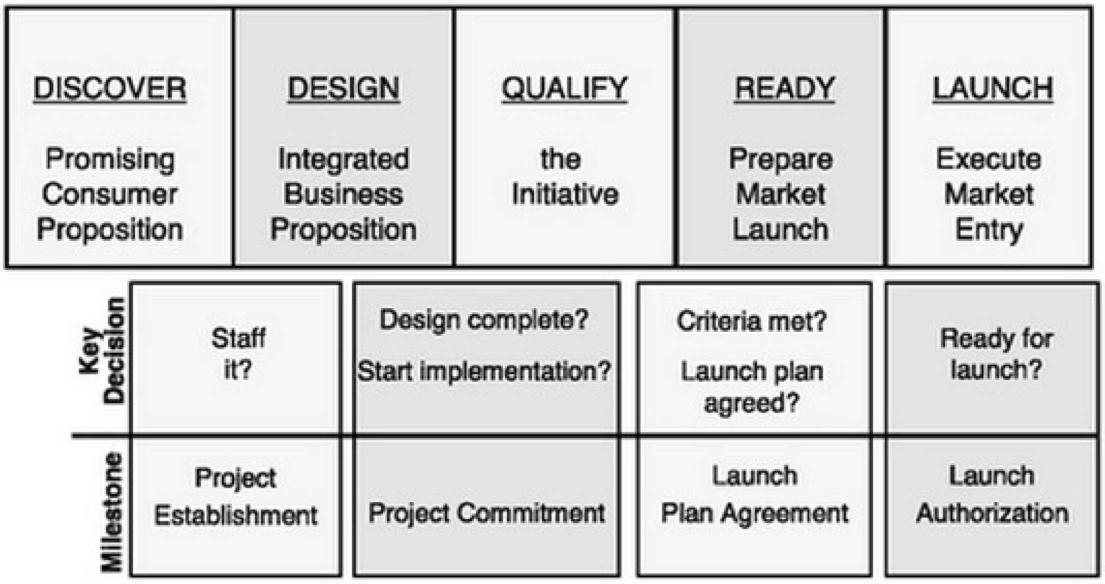


Figure 3.17 SIMPL stage-gate process

Exxon Chemical Company firstly used Stage-Gate process in its Polymers business unit in the late 1980s. In the following year, company developed PIP (Product Innovation Process) system. Day by day, PIP system has been modified and adapted to next generation Stage-Gate approach. Gate-1 (Idea Screen) is especially important to start a NPD project in Exxon. The new product must be fit to a business area of the market strategically. Market opportunity should be attractive. Moreover, the product must be feasible from technical side. If new product covers all of these features and does not have any specific killer variables, the project can be started [29].

Lego, a Danish toy manufacturer, renovates its production line to be able to produce new kind of toys every year. In order to launch new products rapidly and consistently in every year, the company was looking for a process. Today, also Lego prefers Stage-Gate new product process to achieve this target [29].

As summary, Stage-Gate methodology becomes more popular for new product development process day by day. In fact, the traditional version of this methodology is old-fashioned. Nowadays, most of companies, which utilize Stage-Gate approach, prefer more flexible, adaptable and scalable version that is called "Next Generation Stage-Gate" model. This model is presented in details in the following clause.

3.5.3 Next Generation Stage-Gate Methodology

In recent years, Stage-Gate process has been evolved and gained new features. Undoubtedly, next generation Stage-Gate process is scalable, flexible, adaptable and efficient. These new features and more will be presented in this clause.

New Stage-Gate approach is scalable for different types of projects. Depending on the customer's requirements and size of the project, Stage-Gate process can be scaled in order to suit any size of project. For large and risky projects, a five stages-five gates methodology is preferred typically. In fact, Gate-1 is very important to scale Stage-Gate because the type of a project and possible risks are handled in this stage. In Figure 3.18, scalability of Stage-Gate approach is demonstrated to practitioners [29]:

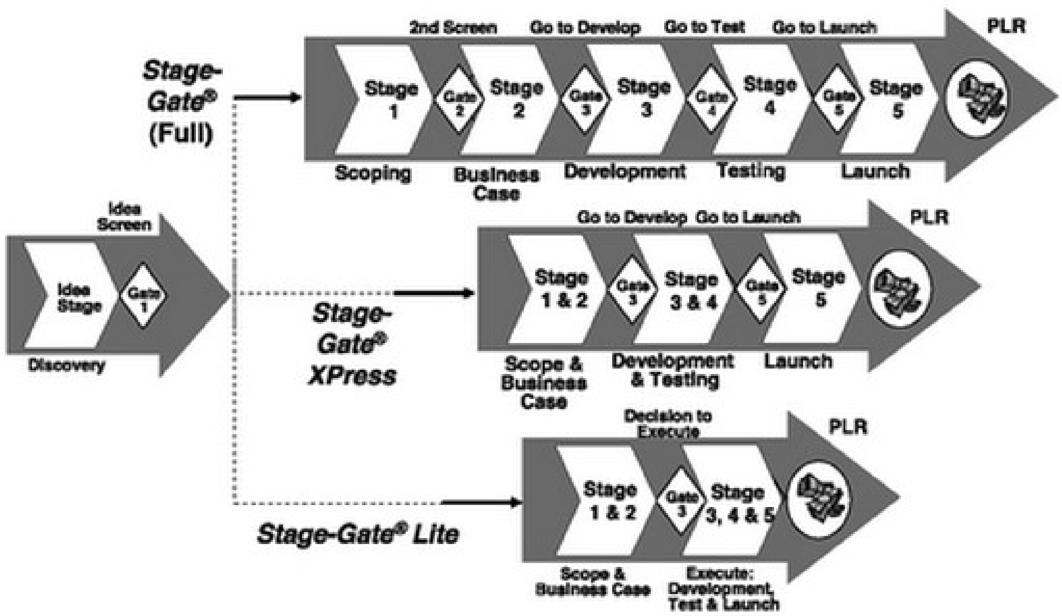


Figure 3.18 Scalable stage-gate processes

For major new product development projects, full version is used. For a project with moderate level of risks, Xpress version is better. For marketing requests and minor changes on products, Lite version is preferred.

New Stage-Gate is also a flexible process that is purged from rigidity of classical methodology. There is no mandatory activity or deliverables. Flexible process consists of simultaneous execution term which advocates overlapping activities within stages and even between stages in order to gain time but however triggers the fire of risks. A simple illustration of overlapping activities within a Stage-Gate process is shown in Figure 3.19 [29];

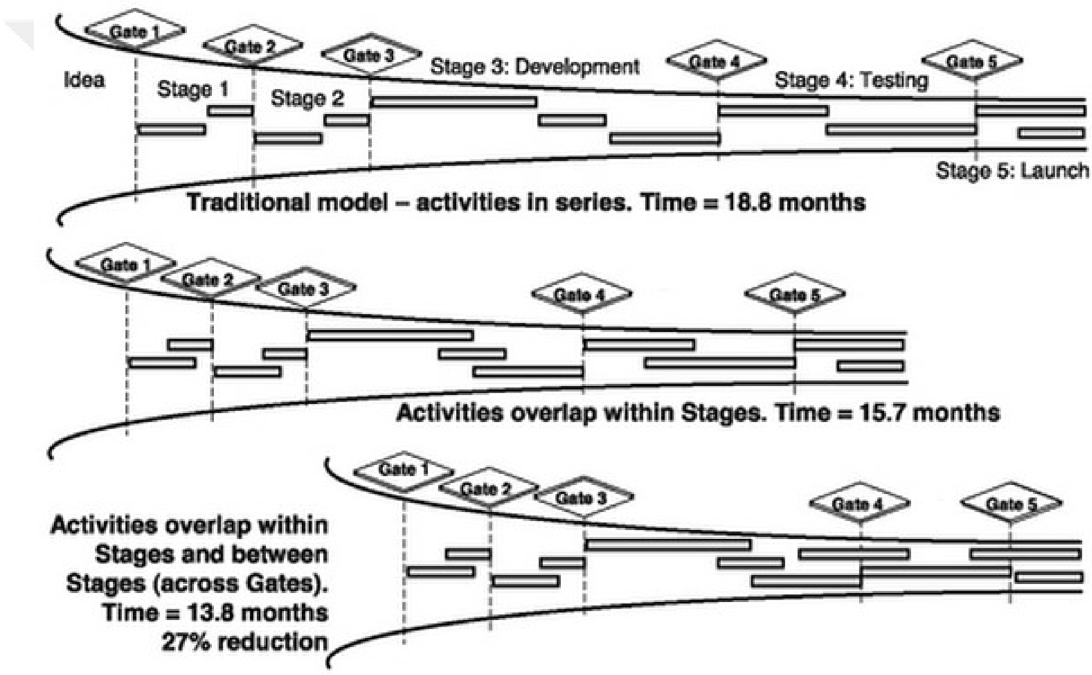


Figure 3.19 Overlapping activities within stage-gate process

What is observed in the figure is that overlapping activities shorten the completion period of the project, especially when activities overlap between stages (27% reduction).

Adaptable and Agile Stage-Gate process will be shared in the next clause as "Spiral Methodology". This methodology is also a Stage-Gate process but it is differentiated from classical Stage-Gate in some resources and called as a project management methodology [9]. So, this methodology will be discussed, separately.

In smart companies, next generation Stage-Gate methodology is lean and purged from any waste and inefficiency. They have quoted Value Stream Map (VSM) from lean methodology and integrated it into Stage-Gate process for new product development projects. How VSM is integrated into Stage-Gate process is demonstrated in Figure 3.20 [29];

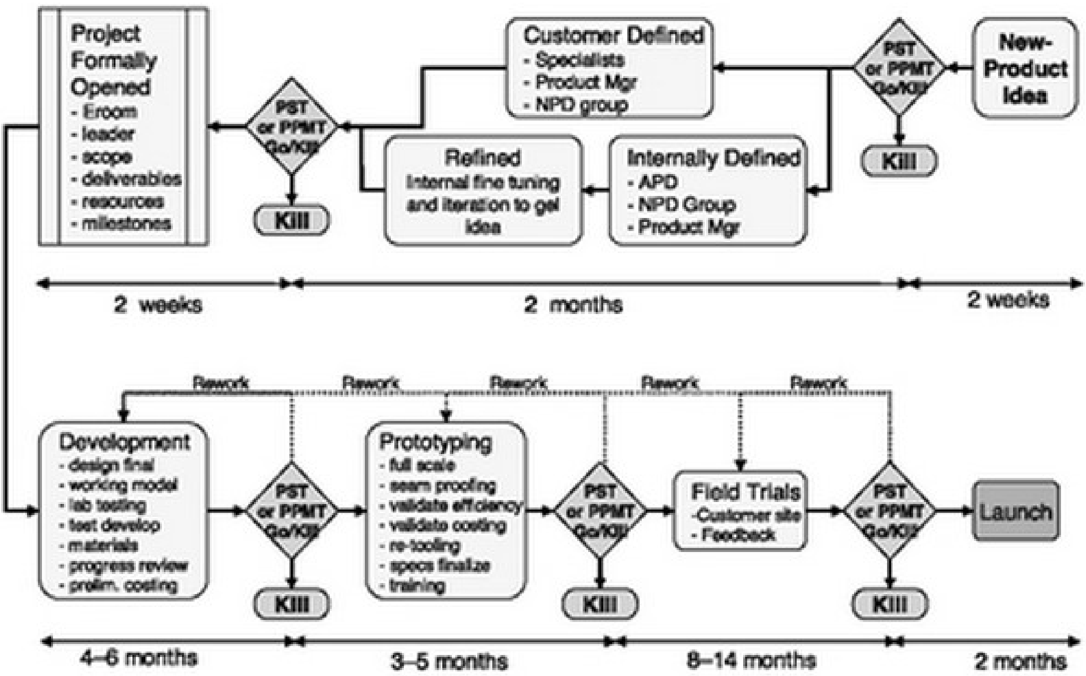


Figure 3.20 Stage-gate process with VSM analysis

As explained at clause 1.5.3 of this thesis, VSM is mainly employed for identifying the non-value-added activities (NVAs), such as reworks and waiting. When it is integrated with Stage-Gate, the methodology is used to improve the idea-to-launch process. All the stages, decision points, and key activities in a typical project are identified in details. Each stages, gates and activities are planned within typical times. All problems, time wasters, and non-value-added activities are caught throughout the process and be removed. As summary, the main goal of Stage-Gate with VSM is maximizing the customer value by assigning specific times for each activities within stages and gates and removing non-value added activities for higher efficiency.

3.6 The Spiral Methodology

This methodology is a version of Stage-Gate methodology, which is more adaptable and agile. The main target is to reach the finalized product design iteratively and rapidly.

Spiral development consists of a series of "build-test-feedback-and-revise" iterations. By the help of these iterations, the product gets closer to the customer's need. Spirals appear in Stage-2 firstly and support to build the business case before the development stage. At Stage-3 and Stage-4, spirals are generated to develop prototypes and test them till reaching to final product. Figure 3.21 illustrates the spirals throughout the Stage-Gate system [29];

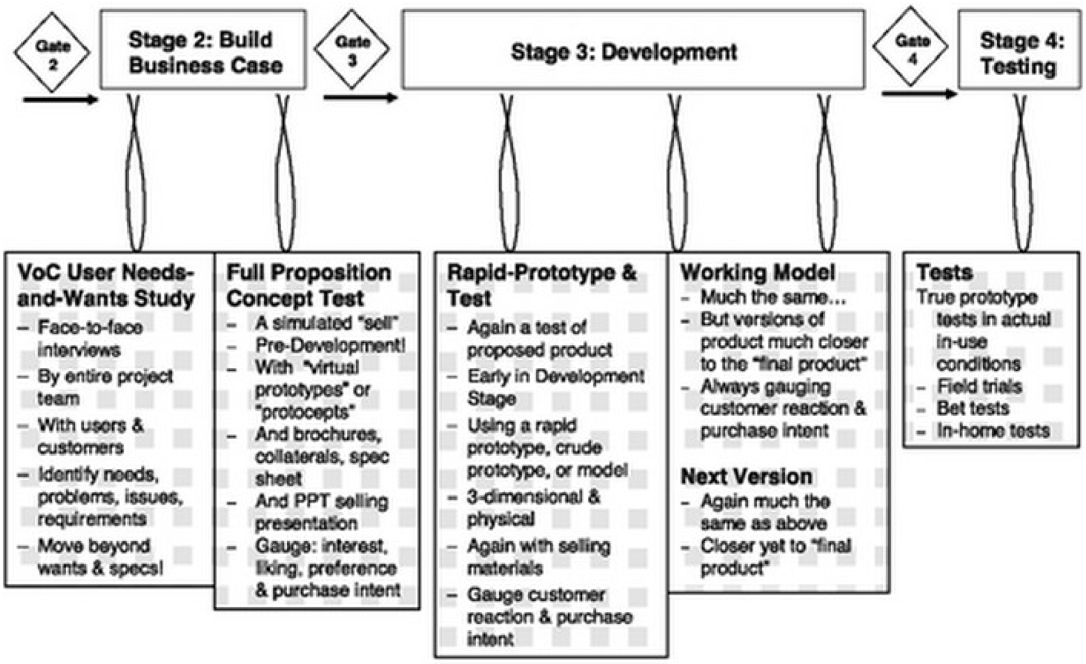


Figure 3.21 Spirals throughout the stage-gate system

The first spiral refers to voice of customer. Generally, project team visits customer to listen customer's needs and identify specifications of new product.

In the second spiral, the project team presents a representation of the proposed product. Depending on the type of product or industry, a part of software or some two dimensional drawings or a hand-made prototype is shared with customer to give an idea about the functionality of the product at the end. The prototype does not work at this early stage. Furthermore, a product and selling presentation is shown to the customer in order to get some feedback and revise the product specs and/or marketing and sales strategy. Lastly, the reaction and feelings of customer for the product are gauged by the project team.

Third spiral consist of creating rapid prototypes to be tested and revised rapidly. Three dimensional models can be shared with customer. Again, product and sales presentations are prepared and customer reaction and purchase intent are reviewed.

In the fourth spiral, a working model of the product is presented to the customer. This model is much closer to the final product. Finally, customer reaction and purchase intent are gauged again.

In this example, there is also fifth spiral that consists of final prototype tests in field, on appliance and in homes. Depending on the feedbacks, the product is revised and tested again. In any case, the number of spirals can be changed regarding customer needs, the size of the project, the company culture or any other parameters. The key point is that each project team creates adequate number of spirals throughout the project. Main target is to be able to match with customer's ideal; in other words, to get closer to the final product which is in customer's mind.

In Chapter-IV, a combined project management methodology for NPD projects, which is proposed as an output from this thesis, will be presented to the researchers. Moreover, a mathematical approach to the project management; "Earned-Value Management" technique will be introduced theoretically.

CHAPTER IV

AN INTEGRATED PROJECT MANAGEMENT APPROACH FOR NEW PRODUCT DEVELOPMENT PROJECTS

4.1 Introduction

Throughout the Chapter-III, different types of popular project management methodologies have been presented to researchers. Generally, there are many other types based on PMBOK® or PRINCE2™ [31] methods. For NPD projects, the most popular ones have been mentioned.

As a general review, "waterfall methodology" is convenient for software development projects. All stages of the development projects are proceeded consecutively and it is really hard to go back after you go down to the other step. This methodology is very old-fashioned and nowadays, more advanced methods are used for software development projects. As mentioned in the clause 2.2 and 2.5.2, the winner of PMO of the year award in 2009, Rockwell Automation Company had given up waterfall model and chosen CPD model. Iterations are very important for software development projects since these projects should always be flexible for customer's variable needs and they should be adaptable to the unexpected cases.

"Agile methodology" is another popular one for software development projects. This method is more advanced than waterfall methodology. First of all, agile approach is iterative. There are some revisions during the development and software is always adaptable to changes. Agile approach aims to give fast responses to customer's needs and requirements. Verification is made at each stage of the project; not only at final stage like waterfall approach. The visibility of the agile project is high. There are working software at each iteration; not only prototypes. However, this methodology is not adaptable to all phases of NPD projects directly. Even if agile methodology consists of some sub-methods inside (Extreme Programming, Scrum, RAD, DSDM, Lean Development and etc…), all them can be used for only software development part of an NPD project. Generally, NPD projects need to be managed through more complex methodologies in order to achieve separate branches of overall project.

The other project management methodology is "Lean Six Sigma (LSS)" that focuses on improving quality, reducing waste and increasing speed of the process. That is occurred by combining Lean manufacturing and Six Sigma methodologies. Lean methodology brings faster process in production lines and Six Sigma methodology provides the lowest level of variance on quality. Hence, the quality of new product will be better and the cost and time saving will be achieved in production. Generally, Lean Six Sigma is a very useful methodology for process improvement projects and can be a part of overall NPD projects. Briefly, Lean Six Sigma is not a direct method to manage a total NPD project. It can support NPD project management in terms of process improvement.

Stage-Gate methodology is a very popular NPD project management methodology that is commonly used in worldwide known companies. This methodology divides the entire project to a series of stages and it reviews these stages by the help of gates. Gates are critical processes to give decisions of Go/Kill for the project by the help of decision criteria. Traditional Stage-Gate and Next Generation Stage-Gate methodologies have already been introduced within previous clauses of this thesis.

At this chapter, a new approach to Stage-Gate will be introduced to the practitioners and researchers. This approach overcomes the deficiencies of Stage-Gate method in terms of scheduling, risk management, change management and continuous earned value management. *Scheduling* implies timing periods of all stages, work items under stages, gates and review meetings under gates. All work items are listed and scheduled through any special software. "MS Project" will be introduced within this thesis as a scheduling and planning tool. *Risk management* is utilized to predict possible risks and put all risks into "risk matrix" to scale the severity and likelihood of a risk. Subsequently, "mitigation and contingency plan" is prepared. *Change management* is used to create "change gates" in order to manage unexpected changes during the project. *Continuous Earned-Value Management* is used to measure the total performance of the project at the end of each stage.

4.2 An Integrated PM Methodology for NPD Projects

4.2.1 Schedule-Oriented Stage-Gate Method

Planning and Scheduling are very complex terms in the scope of project time management. Therefore, planning and scheduling methodologies are needed to be clarified prior to implementing these terms to the Stage-Gate system.

Generally, project managers are responsible for generating a project planning, executing this planning and controlling the whole plan within a closed-loop system. The main tasks of a successful project manager are to consider the project planning as an iterative process and to keep planning activities being performed during the life of the project.

According to Kernzer, there are four reasons for project planning, basically [4];

- To eliminate or reduce uncertainty
- To improve efficiency of the operation
- To obtain a better understanding of the objectives
- To provide a basis for monitoring and controlling work

In order to perform the planning activities within a general project plan, Kernzer proposes a closed-loop control system that includes all necessary activities for a project. This system is illustrated as a flow diagram in Figure 4.1 [4]. Firstly, the goals/objectives of the project are determined. Then, work description is made and Work Breakdown Structure (WBS) is built. WBS term will be explained within this clause in details. The third process is designing a Network Scheduling. Network Scheduling consists of PERT and CPM methods. These methods also will be explained within this clause in details. After network scheduling, a Master Schedule is made. This schedule includes all details of activities and consecutive timing. The following process is Budget controlling. In fact, budget and timing are reviewed together for a realistic evaluation of project performance. Therefore, the next process is Time-Cost-Performance Tracking of the project. As a result of this process, the current situation is reported to upper management for Decision-Making process.

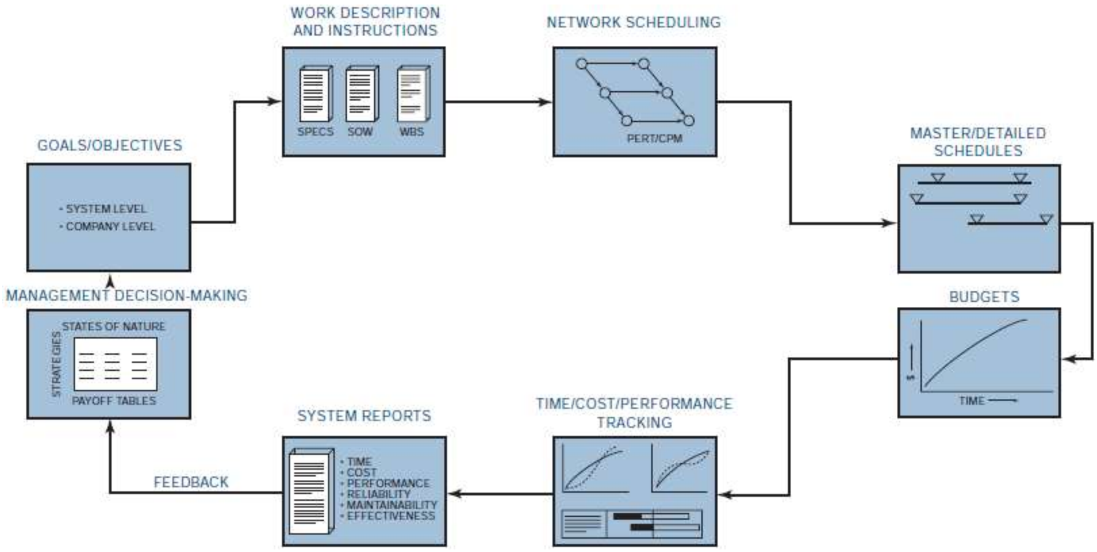


Figure 4.1 Project planning closed-loop system

In order to clarify all parts within this closed-loop system, some of terms will be described in details within sub-clauses.

4.2.1.1 Work Breakdown Structure (WBS)

WBS is a tool which is used for subdividing project deliverables and project work into smaller and easily manageable parts to produce the final product [1]. Generally, WBS is a very important element to [4]:

- ✓Define subdivided elements
- ✓Perform planning
- ✓Build cost and budget structure
- ✓Track time, cost and performance
- ✓Link objectives to company resources
- ✓Establish schedules and status-reporting procedures
- ✓Develop network construction and control planning
- ✓Establish responsibility assignments for each element

WBS can be configured as a "tree diagram" on simple projects. A simple tree diagram is illustrated in Figure 4.2 [4];

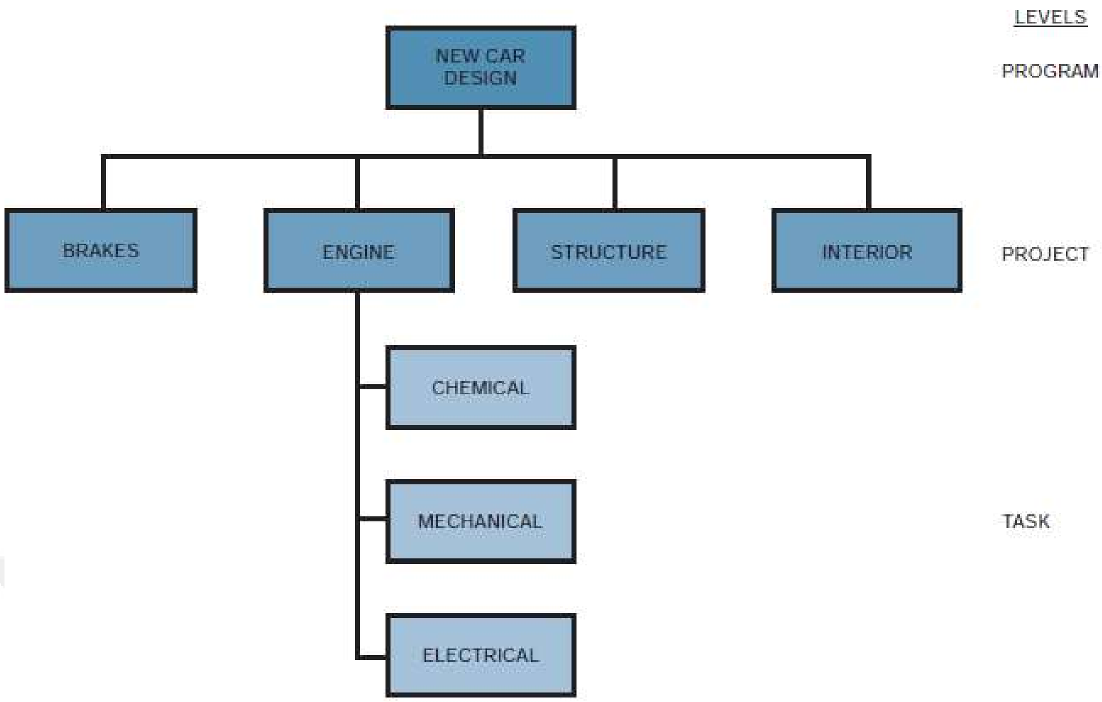


Figure 4.2 WBS tree diagram

There are three common methods in order to build a WBS. These methods are called as "flow method, life cycle method and organization methods". The methods are shown in the Table 4.1 below [4];

	Method		
Level	**Flow**	**Life Cycle**	**Organization**
Program	Program	Program	Program
Project	System	Life cycle	Division
Task	Subsystem	System	Department
Subtask	People	Subsystem	Section
Work package	People	People	People
Level of effort	People	People	People

Table 4.1 WBS Methods

Generally, the flow method is proper for the projects less than two years in length. It includes the systems and crucial subsystems. Life-cycle method is proposed for longer projects. The structure of this method is same as flow method. For the repetitive projects, the organization method is well-suited. Moreover, that method is used for correlating departments.

4.2.1.2 Network Scheduling

Network scheduling is a technique that helps to manage a project efficiently. The most popular scheduling techniques are listed below [4];

- Gantt or bar charts
- Milestone charts
- Networks
- Program Evaluation and Review Techniques (PERT)
- Critical Path Method (CPM)
- Precedence Diagram Method (PDM)
- Graphical Evaluation and Review Techniques (GERT)

Generally, Gantt and milestone charts are inadequate to demonstrate the interdependencies between events and activities. In order to achieve a master plan, these interdependencies must be clarified.

The construction of the networks is used to show these interdependencies. The main purpose of network analysis is providing valuable information for planning, integration of plans, time studies, scheduling, and resource management. Networks consist of events and activities. In order to understand networks clearly, the following terms can be helpful [4]:

- ✓ *Event:* Equivalent to a milestone that indicates when an activity starts or finishes.
- ✓ *Activity:* The element of work that must be accomplished.
- ✓ *Duration:* The total time required to complete the activity.
- ✓ *Effort:* The amount of work that is actually performed within the duration. For example, the duration of an activity could be one month but the effort could be just a two-week period within the duration.
- ✓ *Critical Path:* This is the longest path through the network and determines the duration of the project. It is also the shortest amount of time necessary to accomplish the project.

PERT is a basic management planning and control tool. It can be considered as a road map of a project in which all major events have been completely identified. It is structured from back to front. In other words, the due date is fixed at the beginning of the project and the front-end is built flexibly. In Figure 4.3 [4], a standard PERT terminology is shown:

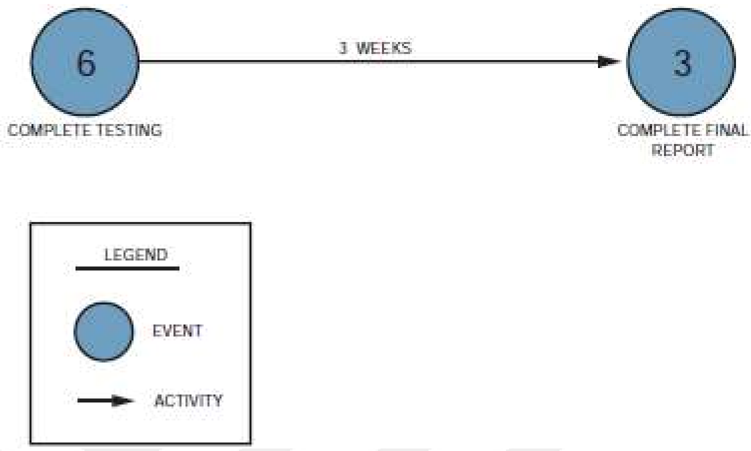


Figure 4.3 Standard PERT terminology

Since the Gantt and milestone charts are insufficient, PERT chart can be developed by making conversion just as it is illustrated in Figure 4.4 [4]: Firstly, Gantt (bar) chart is converted to milestone chart. After that, PERT is structured by defining the relationship between the events on different bars in the milestone chart.

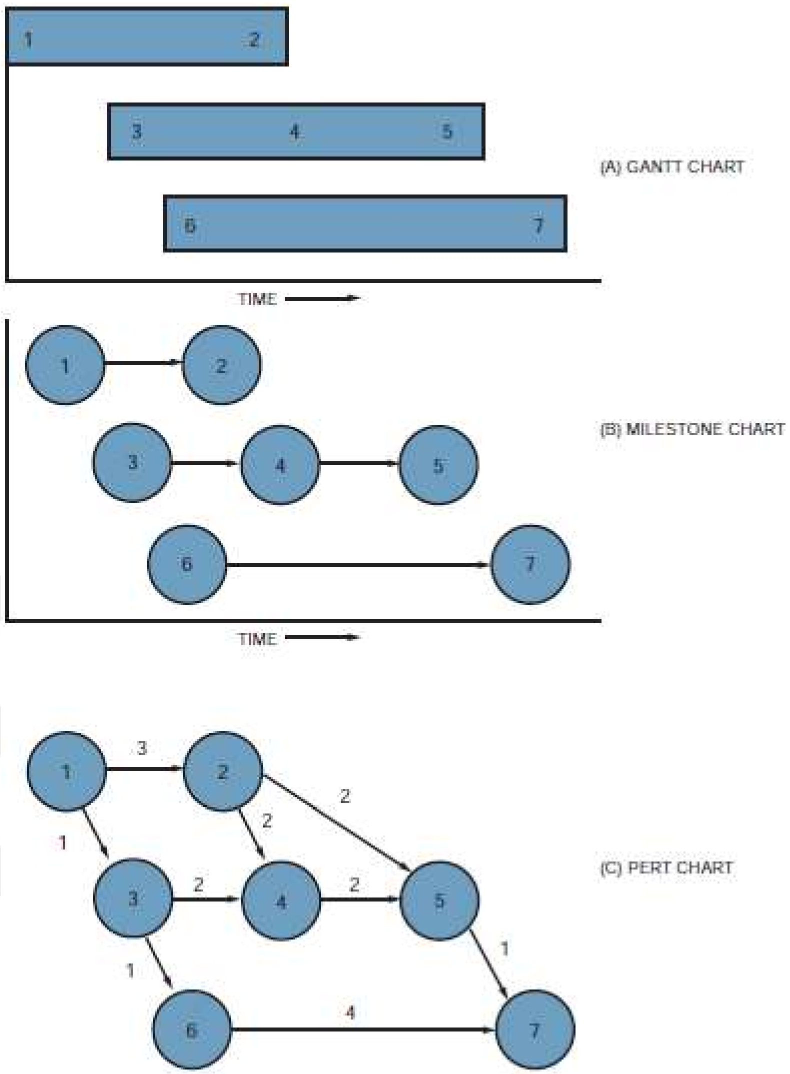


Figure 4.4 Conversion from Gantt-chart to PERT chart

In reality, nomenclature of PERT and CPM techniques are same. Moreover, both techniques are known as arrow diagramming methods. Nevertheless, there are some differences between PERT and CPM which are listed below [4]:

- PERT uses three time estimates called as optimistic, most likely and pessimistic to calculate an expected time between events (activity time). CPM uses only one time estimate that demonstrates the normal time.
- PERT is probabilistic in nature but CPM is deterministic. PERT is based on a beta distribution for each activity time and a normal distribution for total project time. Therefore, the risk in completing a project can be calculated.

CPM is based on a single time estimate. Figure 4.5 shows the critical path (single time estimate) on a PERT network [4]:

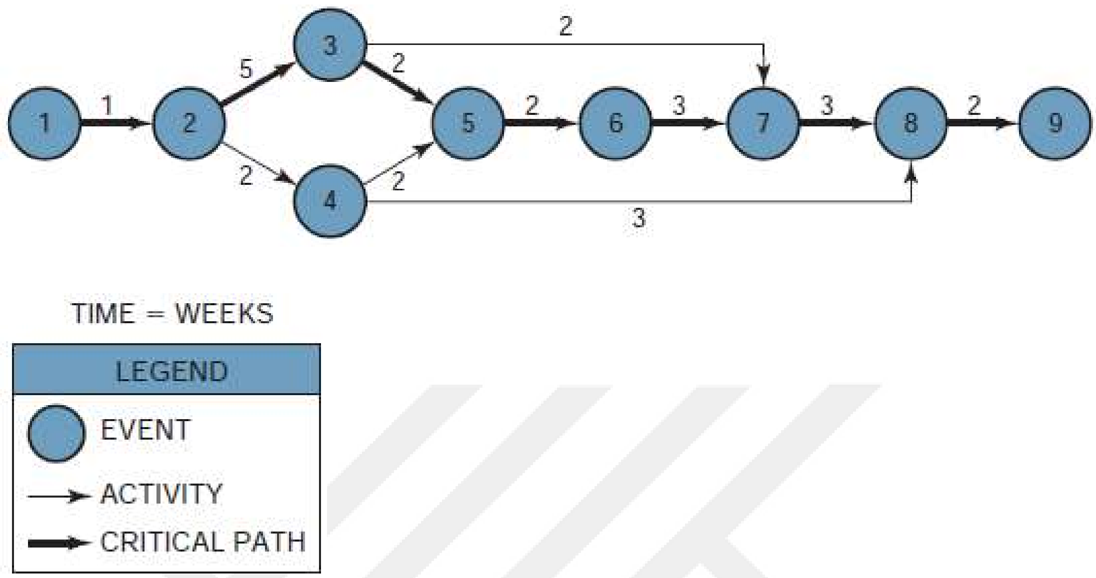


Figure 4.5 Critical path illustration on PERT network

CPM calculates the longest path of planned activities to the end of the project. Time estimation for this critical path is "18 weeks".

- PERT is used for R&D projects where the risks in calculating time durations have a high variability. CPM is used for construction projects that are resource dependent and based on accurate time estimates.
- PERT is used for R&D or other similar projects where percent complete is almost impossible to determine. CPM is used for construction or other similar projects where percent complete may be determined with reasonable accuracy. Hence, customer billing can be achieved based on percent complete.

Both CPM and PERT needs dummy activities to develop network dependencies. Dummy activities added into the network to complete the logic. Figure 4.6 shows a dummy activity simply:

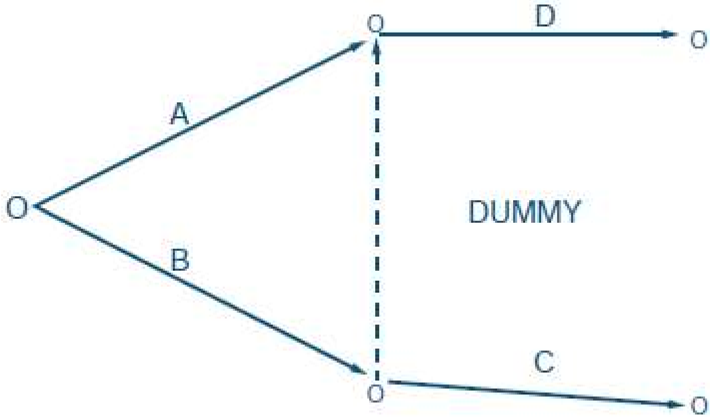


Figure 4.6 Dummy activity

Let's assume that there is an activity D that should be preceded by both activities A and B. In order to show this on network diagram, a dummy activity is represented by a dotted line. Dummy activities do not consume resources or require time.

While the differences between PERT and CPM are described, estimating activity time and estimating total project time had been mentioned. Activity time can be estimated from the expression [4]:

$$t_e = \frac{a + 4m + b}{6}$$

a = most optimistic time b = most pessimistic time m = most likely time

t_e = expected time

For estimating standard deviation of expected time, the expression is used [4]:

$$\sigma_{t_e} = \frac{b - a}{6}$$

σ_{t_e} = the standard deviation of expected time

Figure 4.7 helps to give an example on estimating activity time and total standard deviation [4]:

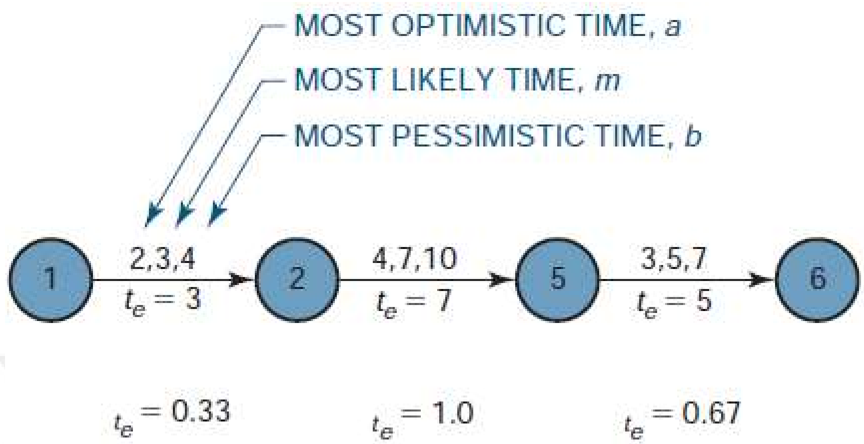


Figure 4.7 Project time analysis

Most optimistic time (a), most likely time (m) and most pessimistic time (b) are shown in the Figure 4.7. Therefore "*te*" may be calculated for all activities:

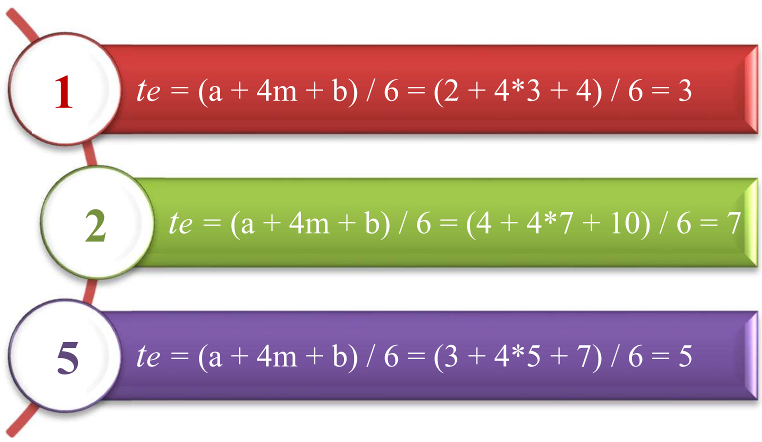


Figure 4.8 Expected time calculation

Standard deviations for all expected times can be calculated as:

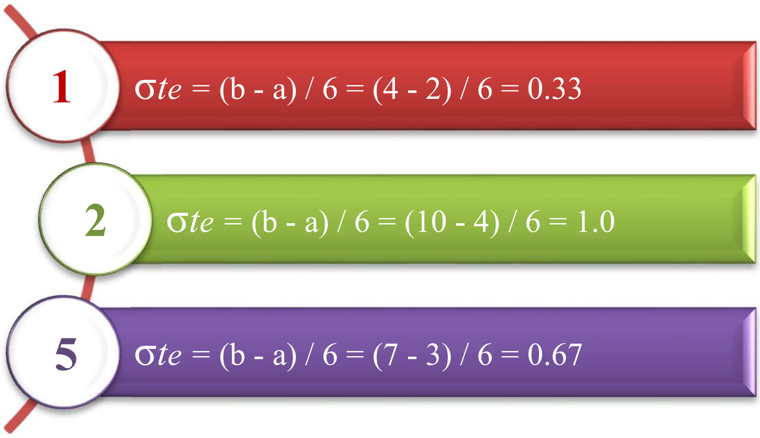


Figure 4.9 Standard deviation of expected time

The total path standard deviation is calculated from the expression below [4]:

$$\sigma_{total} = \sqrt{\sigma_{1-2}^{2} + \sigma_{2-5}^{2} + \sigma_{5-6}^{2}}$$

$$\sigma_{total} = \sqrt{(0.33)^2 + (1.0)^2 + (0.67)^2} = 1.25$$

From the above results, the length of critical (expected) path is “15 weeks (3 + 7 + 5 = 15)”. Also, total path standard deviation (σtotal) is “1.25”. The probability of completing the project within certain time limits can be calculated from statistics by using normal distribution. In the curve of normal distribution, “1.25” sigma refers to 78.88%. In other words, the probability of completing the project within 15 weeks is 78.88%.

4.2.1.3 Master Schedule (MS Project)

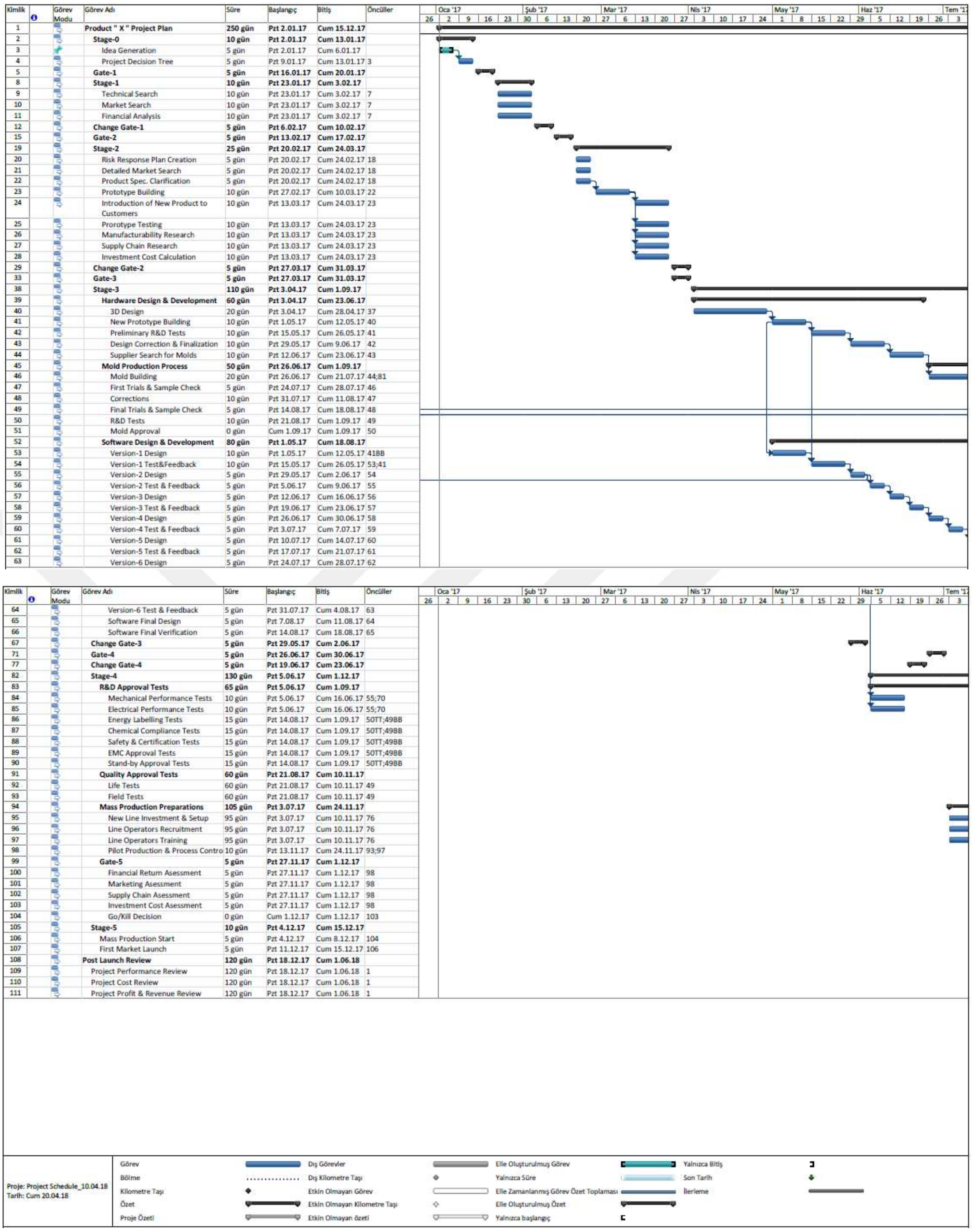
Microsoft (MS) Project has been especially developed for project management and is a useful software application for planning, tracking and controlling a project. MS Project can do the work items which are listed below:

- MS Project is a tool which supports project managers.
- MS Project can do calculations in terms of durations or costs accurately.
- MS Project allows making changes to the project and seeing the effects to those changes before finalizing project plan and committing it to work.
- Once project plan is in action, MS Project can track all the information collected about the work, duration, costs and resource requirements for the project so that some adjustments can be made in order to keep on target.
- MS Project helps to create and print various predefined reports and views quickly.

A simple project plan, which is created to develop a new product, is presented in the Figure 4.10. This plan has been prepared by the help of MS Project 2010 software tool. In the project schedule, six important headlines are presented:

- ✓ *Hardware Design & Development*
- ✓ *Tool Production*
- ✓ *Software Design & Development*
- ✓ *Product Approval & Institute Certification*
- ✓ *Life Tests and Field Tests of Product X*
- ✓ *Mass Production Preparations*

There are some items under each headline and these work items are connected to each other's by the help of predecessors which are placed in the column next to the finish date. Those predecessors connect related work items and track the work through five main constraints illustrated at Figure 4.11 [4].



Kimlik	Görev Adı	Süre	Başlangıç	Bitiş	Öncüller
1	**Product " X " Project Plan**	**250 gün**	**Pzt 2.01.17**	**Cum 15.12.17**	
2	**Stage-0**	**10 gün**	**Pzt 2.01.17**	**Cum 13.01.17**	
3	Idea Generation	5 gün	Pzt 2.01.17	Cum 6.01.17	
4	Project Decision Tree	5 gün	Pzt 9.01.17	Cum 13.01.17	3
5	**Gate-1**	**5 gün**	**Pzt 16.01.17**	**Cum 20.01.17**	
8	**Stage-1**	**10 gün**	**Pzt 23.01.17**	**Cum 3.02.17**	
9	Technical Search	10 gün	Pzt 23.01.17	Cum 3.02.17	7
10	Market Search	10 gün	Pzt 23.01.17	Cum 3.02.17	7
11	Financial Analysis	10 gün	Pzt 23.01.17	Cum 3.02.17	7
12	**Change Gate-1**	**5 gün**	**Pzt 6.02.17**	**Cum 10.02.17**	
15	**Gate-2**	**5 gün**	**Pzt 13.02.17**	**Cum 17.02.17**	
19	**Stage-2**	**25 gün**	**Pzt 20.02.17**	**Cum 24.03.17**	
20	Risk Response Plan Creation	5 gün	Pzt 20.02.17	Cum 24.02.17	18
21	Detailed Market Search	5 gün	Pzt 20.02.17	Cum 24.02.17	18
22	Product Spec. Clarification	5 gün	Pzt 20.02.17	Cum 24.02.17	18
23	Prototype Building	10 gün	Pzt 27.02.17	Cum 10.03.17	22
24	Introduction of New Product to Customers	10 gün	Pzt 13.03.17	Cum 24.03.17	23
25	Prorotype Testing	10 gün	Pzt 13.03.17	Cum 24.03.17	23
26	Manufacturability Research	10 gün	Pzt 13.03.17	Cum 24.03.17	23
27	Supply Chain Research	10 gün	Pzt 13.03.17	Cum 24.03.17	23
28	Investment Cost Calculation	10 gün	Pzt 13.03.17	Cum 24.03.17	23
29	**Change Gate-2**	**5 gün**	**Pzt 27.03.17**	**Cum 31.03.17**	
33	**Gate-3**	**5 gün**	**Pzt 27.03.17**	**Cum 31.03.17**	
38	**Stage-3**	**110 gün**	**Pzt 3.04.17**	**Cum 1.09.17**	
39	**Hardware Design & Development**	**60 gün**	**Pzt 3.04.17**	**Cum 23.06.17**	
40	3D Design	20 gün	Pzt 3.04.17	Cum 28.04.17	37
41	New Prototype Building	10 gün	Pzt 1.05.17	Cum 12.05.17	40
42	Preliminary R&D Tests	10 gün	Pzt 15.05.17	Cum 26.05.17	41
43	Design Correction & Finalization	10 gün	Pzt 29.05.17	Cum 9.06.17	42
44	Supplier Search for Molds	10 gün	Pzt 12.06.17	Cum 23.06.17	43
45	**Mold Production Process**	**50 gün**	**Pzt 26.06.17**	**Cum 1.09.17**	
46	Mold Building	20 gün	Pzt 26.06.17	Cum 21.07.17	44;81
47	First Trials & Sample Check	5 gün	Pzt 24.07.17	Cum 28.07.17	46
48	Corrections	10 gün	Pzt 31.07.17	Cum 11.08.17	47
49	Final Trials & Sample Check	5 gün	Pzt 14.08.17	Cum 18.08.17	48
50	R&D Tests	10 gün	Pzt 21.08.17	Cum 1.09.17	49
51	Mold Approval	0 gün	Cum 1.09.17	Cum 1.09.17	50
52	**Software Design & Development**	**80 gün**	**Pzt 1.05.17**	**Cum 18.08.17**	
53	Version-1 Design	10 gün	Pzt 1.05.17	Cum 12.05.17	41BB
54	Version-1 Test&Feedback	10 gün	Pzt 15.05.17	Cum 26.05.17	53;41
55	Version-2 Design	5 gün	Pzt 29.05.17	Cum 2.06.17	54
56	Version-2 Test & Feedback	5 gün	Pzt 5.06.17	Cum 9.06.17	55
57	Version-3 Design	5 gün	Pzt 12.06.17	Cum 16.06.17	56
58	Version-3 Test & Feedback	5 gün	Pzt 19.06.17	Cum 23.06.17	57
59	Version-4 Design	5 gün	Pzt 26.06.17	Cum 30.06.17	58
60	Version-4 Test & Feedback	5 gün	Pzt 3.07.17	Cum 7.07.17	59
61	Version-5 Design	5 gün	Pzt 10.07.17	Cum 14.07.17	60
62	Version-5 Test & Feedback	5 gün	Pzt 17.07.17	Cum 21.07.17	61
63	Version-6 Design	5 gün	Pzt 24.07.17	Cum 28.07.17	62
64	Version-6 Test & Feedback	5 gün	Pzt 31.07.17	Cum 4.08.17	63
65	Software Final Design	5 gün	Pzt 7.08.17	Cum 11.08.17	64
66	Software Final Verification	5 gün	Pzt 14.08.17	Cum 18.08.17	65
67	**Change Gate-3**	**5 gün**	**Pzt 29.05.17**	**Cum 2.06.17**	
71	**Gate-4**	**5 gün**	**Pzt 26.06.17**	**Cum 30.06.17**	
77	**Change Gate-4**	**5 gün**	**Pzt 19.06.17**	**Cum 23.06.17**	
82	**Stage-4**	**130 gün**	**Pzt 5.06.17**	**Cum 1.12.17**	
83	**R&D Approval Tests**	**65 gün**	**Pzt 5.06.17**	**Cum 1.09.17**	
84	Mechanical Performance Tests	10 gün	Pzt 5.06.17	Cum 16.06.17	55;70
85	Electrical Performance Tests	10 gün	Pzt 5.06.17	Cum 16.06.17	55;70
86	Energy Labelling Tests	15 gün	Pzt 14.08.17	Cum 1.09.17	50TT;49BB
87	Chemical Compliance Tests	15 gün	Pzt 14.08.17	Cum 1.09.17	50TT;49BB
88	Safety & Certification Tests	15 gün	Pzt 14.08.17	Cum 1.09.17	50TT;49BB
89	EMC Approval Tests	15 gün	Pzt 14.08.17	Cum 1.09.17	50TT;49BB
90	Stand-by Approval Tests	15 gün	Pzt 14.08.17	Cum 1.09.17	50TT;49BB
91	**Quality Approval Tests**	**60 gün**	**Pzt 21.08.17**	**Cum 10.11.17**	
92	Life Tests	60 gün	Pzt 21.08.17	Cum 10.11.17	49
93	Field Tests	60 gün	Pzt 21.08.17	Cum 10.11.17	49
94	**Mass Production Preparations**	**105 gün**	**Pzt 3.07.17**	**Cum 24.11.17**	
95	New Line Investment & Setup	95 gün	Pzt 3.07.17	Cum 10.11.17	76
96	Line Operators Recruitment	95 gün	Pzt 3.07.17	Cum 10.11.17	76
97	Line Operators Training	95 gün	Pzt 3.07.17	Cum 10.11.17	76
98	Pilot Production & Process Contro	10 gün	Pzt 13.11.17	Cum 24.11.17	93;97
99	**Gate-5**	**5 gün**	**Pzt 27.11.17**	**Cum 1.12.17**	
100	Financial Return Asessment	5 gün	Pzt 27.11.17	Cum 1.12.17	98
101	Marketing Asessment	5 gün	Pzt 27.11.17	Cum 1.12.17	98
102	Supply Chain Asessment	5 gün	Pzt 27.11.17	Cum 1.12.17	98
103	Investment Cost Asessment	5 gün	Pzt 27.11.17	Cum 1.12.17	98
104	Go/Kill Decision	0 gün	Cum 1.12.17	Cum 1.12.17	103
105	**Stage-5**	**10 gün**	**Pzt 4.12.17**	**Cum 15.12.17**	
106	Mass Production Start	5 gün	Pzt 4.12.17	Cum 8.12.17	104
107	First Market Launch	5 gün	Pzt 11.12.17	Cum 15.12.17	106
108	**Post Launch Review**	**120 gün**	**Pzt 18.12.17**	**Cum 1.06.18**	
109	Project Performance Review	120 gün	Pzt 18.12.17	Cum 1.06.18	1
110	Project Cost Review	120 gün	Pzt 18.12.17	Cum 1.06.18	1
111	Project Profit & Revenue Review	120 gün	Pzt 18.12.17	Cum 1.06.18	1

Figure 4.10 Simple schedule of a NPD on MSP program

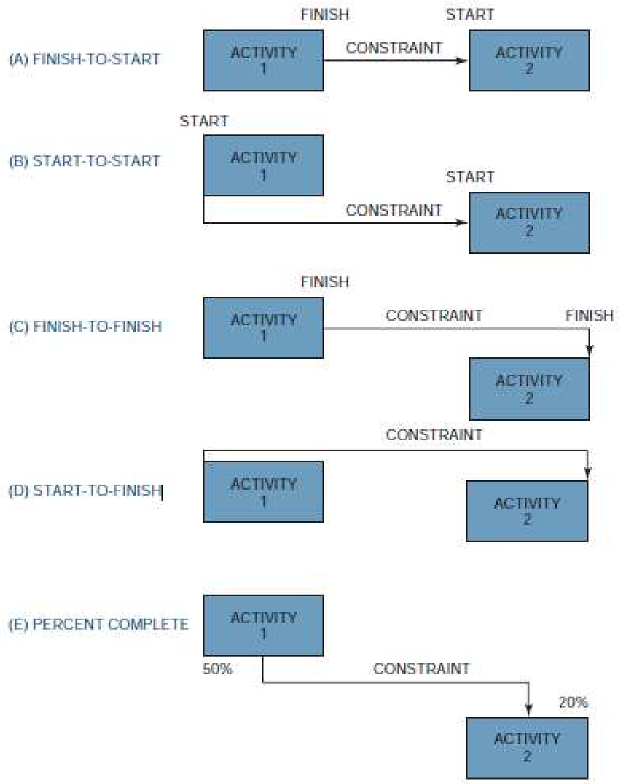


Figure 4.11 Constraints within schedule

Finish-to-Start (FS) constraint means activity 2 cannot start earlier than the completion of activity 1. Start-to-Start (SS) constraint means activity 2 cannot start prior to the start of activity 1. Finish-to-Finish (FF) constraint means activity 2 cannot finish until activity 1 finishes. Start-to-Finish (SF) constraint means activity 2 cannot finish prior to activity 1 starts. Also, there can be a lag between activities. For example, if activity 1 finishes at week 35, activity should start at the beginning of week 36 in case a finish-to-start constraint. If activity 2 starts at week 37, it means there are two weeks lag. These constraints are utilized in project plan, effectively.

4.2.1.4 Implementation of Scheduling to Stage-Gate Process

Stage-gate methodology, which is applied to new product development projects, consists of six stages and six gates before mass production. As discussed in the master schedule clause (4.2.1.3), an NPD project can be scheduled classically through MS project. Schedules of the projects are generally built on development stages and decision gates are not added in a classical project plan. This thesis proposes to build a total project schedule that includes stages, gates and change gates (will be described within change management clause 4.2.3) in MS project program. The schedule can be built in the Stage-2 since the product specifications are clarified in details at this stage. Stages and gates can be related to each other's through predecessors. If there are any changes or new requirements after a gate review, the project schedule is revised to add a change gate or new tasks within related stage. In this way, the project schedule is much more dynamic. All the stages, gates and new tasks are under control of timing, strictly. Hence, the project manager observes the whole project on the table and considers that how each change impacts the project plan, effectively. As a conclusion, the management of all project tasks can be able to be achieved in a perfect way.

4.2.2 Risk Management

According to Kernzer [4], risk has two important components; one is the probability of the occurrence of an event and the other one is the consequence (impact) of occurrence of an event. In other words, risk can be defined as a function of probability and consequence. The Figure 4.12 presents risk components in a graph:

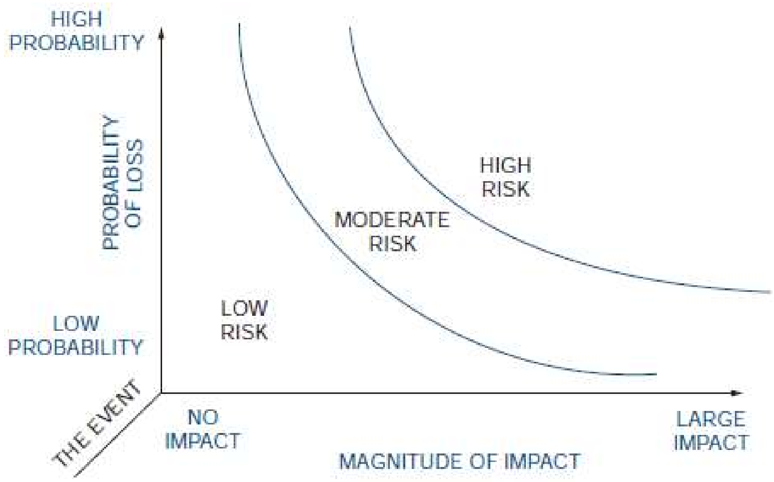


Figure 4.12 Components of risk function

The graph shows that either probability or consequence (impact) increases, risk also increases. If both increase, risk is very high.

As a clear definition, risk management is a process which identifies and measures the risks principally and then it mitigates those risks by developing contingency strategies [8]. Risk management comprises following processes [1]:

- ✓ *Risk Management Planning:* Defining of risk management activities and methods for application.
- ✓ *Risk Identification:* The process of specifying risk that can affect the project.
- ✓ *Qualitative Risk Analysis:* The process of prioritizing of the risks and reviewing their probability of occurrence and their impact.
- ✓ *Quantitative Risk Analysis:* The methodology that analyses the effect of identified risks on the project objectives, numerically.
- ✓ *Planning Risk Response:* The process of creating new options and plans to reduce impact of risks on the objectives.
- ✓ *Monitoring & Controlling Risks:* The process of tracking residual risks, identifying new risks and applying risk response plans to increase the possibility of project success.

4.2.2.1 Risk Management Processes

Raydugin defines project risk management system as a symphony orchestra that consists of mutually complementary instruments and their performers [3]. All parts of the orchestra should be well synchronized to ensure proper overall performance. All members of project team should apply risk management process perfectly to play in unison like an orchestra.

In order to keep the unison of the orchestra, PMBOK proposes to implement six steps of project risk management system which are shared in the previous clause as simple definitions. These processes can be implemented to the some stages of the project in case stage-gate methodology is used just like this thesis proposes. In case the stages are overlapped between each other's, the processes can be overlapped as expected. In this clause, these processes will be presented in details [1].

Risk Management Planning

This process defines how risk management activities can be applied to the project. This process is the base of other five ones. Risk management plan includes the following prominent items:

- ✓ *Methodology:* Defines the approaches -shared by team members or managers-, tools and sources in the organization.
- ✓ *Roles and Responsibilities:* Addresses each type of activities to the project team members and defines their responsibilities.
- ✓ *Budgeting:* Defines resources and funds for application of contingency plans.
- ✓ *Timing:* Establishes risk management activities into total project schedule.
- ✓ *Risk Categories:* Categorizes the risks within a risk break-down structure. A simple illustration of a RBS is shared in Figure 4.13:

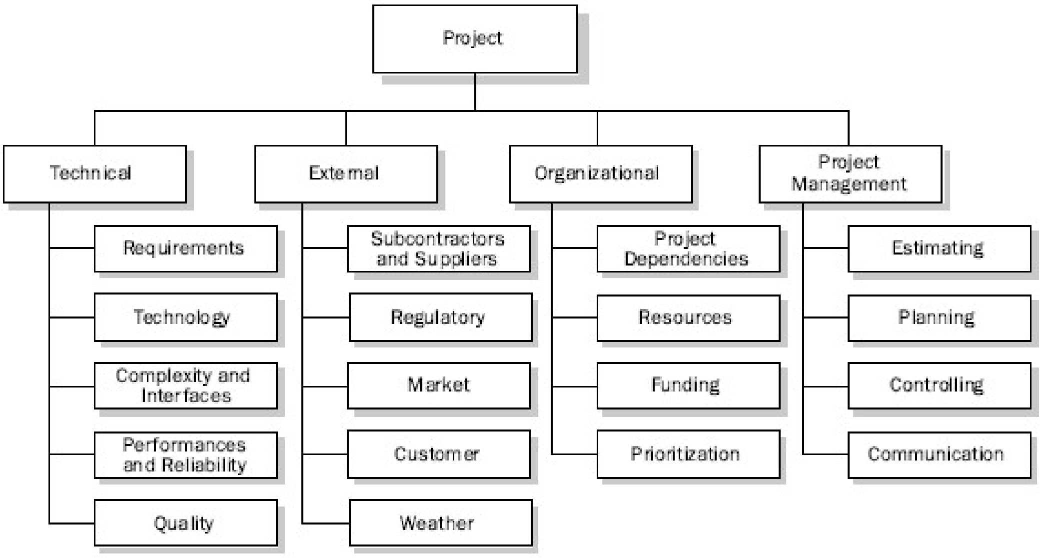


Figure 4.13 Risk Breakdown Structure (RBS)

RBS categorizes and sub-categorizes all possible risks for an NPD project. Sub-categories can be defined in details depending on the project stages. Each stage could have different types of risks. Therefore, RBS should be adaptable to the each stage if needed.

✓ *Definitions of risk probability and impact:* Defines the probability of identified risks versus their impact on the project objectives. Figure 4.14 presents a simple table of risk probability and impacts on the cost, time, scope and quality parameters of a project:

Defined Conditions for Impact Scales of a Risk on Major Project Objectives (Examples are shown for negative impacts only)					
	Relative or numerical scales are shown				
Project Objective	Very low /.05	Low /.10	Moderate /.20	High /.40	Very high /.80
Cost	Insignificant cost increase	<10% cost increase	10-20% cost increase	20-40% cost increase	>40% cost increase
Time	Insignificant time increase	<5% time increase	5-10% time increase	10-20% time increase	>20% time increase
Scope	Scope decrease barely noticeable	Minor areas of scope affected	Major areas of scope affected	Scope reduction unacceptable to sponsor	Project end item is effectively useless
Quality	Quality degradation barely noticeable	Only very demanding applications are affected	Quality reduction requires sponsor approval	Quality reduction unacceptable to sponsor	Project end item is effectively useless

Figure 4.14 Impact scales for project objectives

✓ *Probability and Impact Matrix:* Presents probability of identified risks and impacts as a matrix.

The items mentioned above are discussed in the meetings in which team members, stakeholders and project manager join and a risk management plan is developed.

Risk Identification

This process is very critical before starting analysis phase. It defines the risks that may affect the project dramatically. Risk identification is an iterative action just like agile project management method. As the project progresses within stages, new risks arise. The project manager and its team should be aware of the relativity between the risks. In other words, one risk can affect also another one. In the earlier stages, such as Stage-0 and Stage-1, total project risk is high because of uncertainties especially on NPD projects. As the stages are progressed, total risk tends to decrease depending on removing uncertainties even if financial risk is increased because of new investments for the manufacturability processes and new developments. Kernzer summarizes the curve of risk and stakes changing among project stages within one graph in Figure 4.15 [4]:

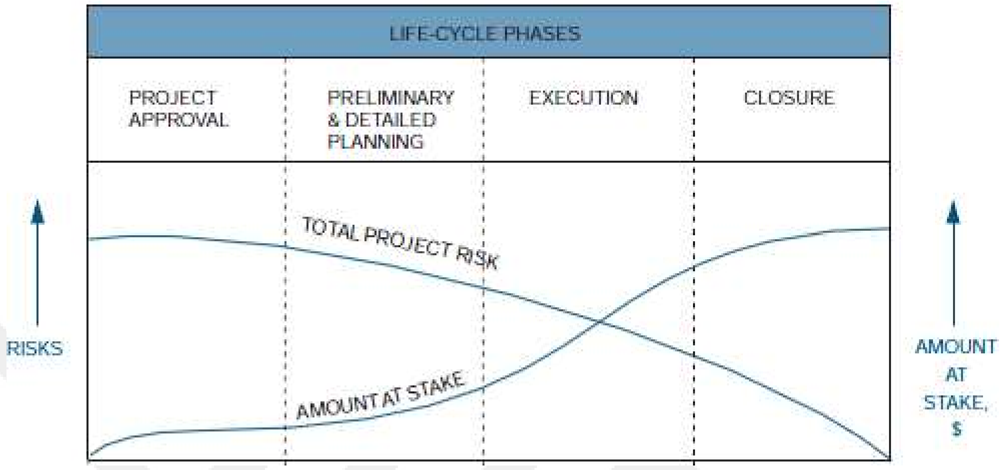


Figure 4.15 Risk Analysis for Project Stages

Risk identification process needs some inputs to determine all possible risk during the project management. First of all, cost and schedule performance indexes are crucial for the project success. Therefore, activity durations and the likely cost to finish scheduled activities are key inputs for risk management. Another important parameter is technical performance. Possible risks for timing, cost and performance should be handled by project management team. Also WBS is a very useful tool to see all work items of the project in details. So, it helps to be aware of possible risks for each step.

There are some techniques to handle risk identification such as fishbone diagrams, process flow charts and SWOT (strengths, weaknesses, opportunities, threats) analysis. Even some organizations hires either consultants or risk experts to manage this process professionally.

After all the risks are listed, a response chart can be generated by the team. This cart can be a good base study for planning risk responses process that is implemented after qualitative and quantitative risk analyses are completed.

Qualitative & Quantitative Risk Analysis

Qualitative risk analysis is a process which is utilized for prioritizing risks and evaluating those risks in terms of probability of occurrence and impact. This process should be kept updated during all the project stages since the risk definitions can be changed from one stage to another one.

Probability and impact matrix is a perfect tool to review the importance of each risk. The Figure 4.16 demonstrates a matrix colored from dark grey to the white depending on the probability of risks:

Probability	Threats					Opportunities				
0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05
0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04
0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03
0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02
0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01
	0.05	0.10	0.20	0.40	0.80	0.80	0.40	0.20	0.10	0.05

Figure 4.16 Probability and impact matrix

The matrix is useful to categorize the risks as “high risk”, “moderate risk” and “low risk”. Categorization can be performed for schedule, cost and technical performance, separately. Hence, the project manager knows very well what risks have highest priority relatively. As an output, mitigation plans can be handled depending on the importance of the risks.

Quantitative risk analysis is a process that analyses the impact of identified risks on the project objectives, numerically. Three main methodologies are utilized in the scope of this analysis.

- *Sensitivity analysis:* That process is used for determining potential impact of a high degree of uncertainty on the project. Tornado diagram is a very useful sensitivity analysis method.

- *Expected monetary value (EMV) analysis:* That process is a statistical way that estimates total outcome of a project by considering possibilities of events that will happen or not. Decision tree diagram is a good method to calculate EMV. Figure 4.17 presents a decision tree diagram:

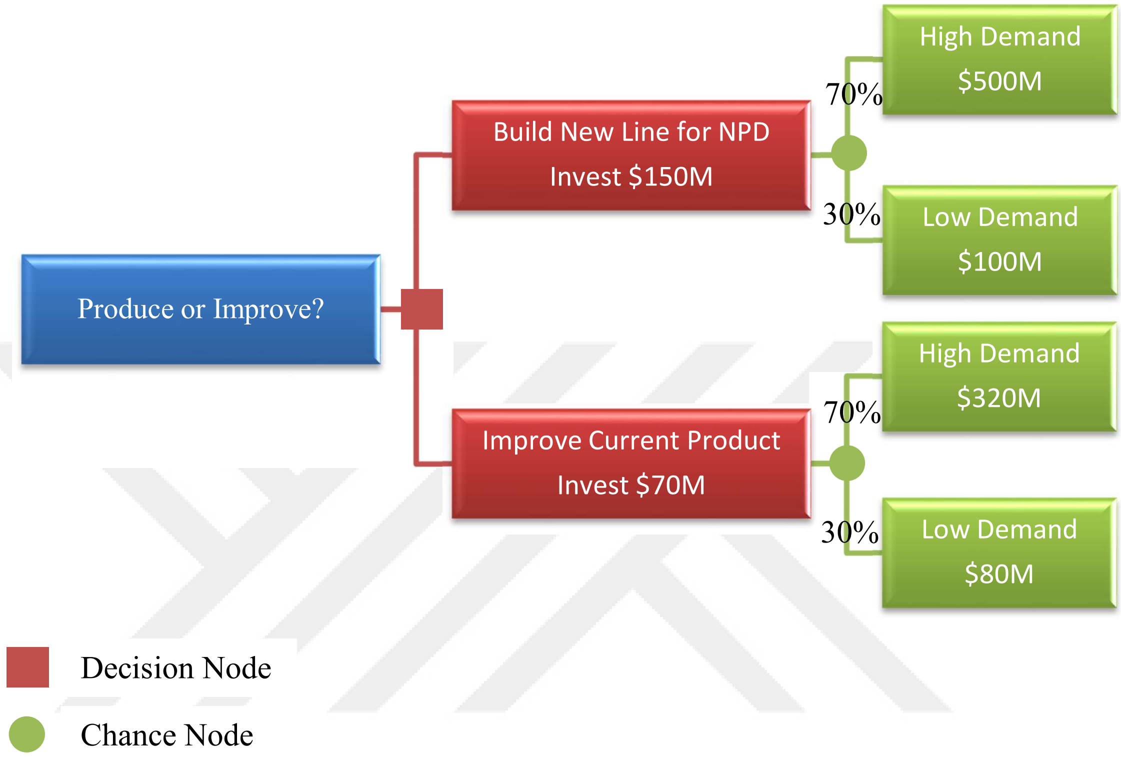


Figure 4.17 Decision Tree Diagram

The decision tree diagram above is designed for a company which tries to estimate which option is more profitable. The options are producing a new product or improving current product. For new product development, company should make an investment for $150M. Improving current product cost for $50M. As a conclusion of the research on the market, company estimates that the possibility of high demand of the potential customers is 70% and low demand possibility is 30%. Finally, EMV calculation is needed to make a decision:

Produce → EMV = [($500M-$150M) x 70%] + [($100M-$150M) x 30%] = $230M

Improve → EMV = [($320M-$70M) x 70%] + [($80M-$70M) x 30%] = $178M

According to EMV calculation, “Produce” option seems more profitable. That is why the company chooses to produce a new product.

- *Modelling and simulation:* That process is used for building a simulation in which the project model is iterated many times. Monte Carlo technique is a popular one for iterative simulations. This technique collects probability distributions for potential risks and then reviews these numbers to build cost, schedule and technical performance risk management for a project [4].

Planning Risk Response

This process consists of a strategy that is utilized to prepare mitigation plans for identified risks. Risk decision tree, risk breakdown structure or any other methods could be useful for planning responses to risks. There are four main response options defined below [1][4]:

- *Acceptance:* Project manager and its team know that there are some risks but no plans or response is prepared. The project management plan is not changed to mitigate a risk. The team works on a risk in case it occurs.
- *Avoidance:* Project manager and its team do not accept any option that can cause problematic results which affect the project performance. In other words, the team avoids taking actions that have high probability of risk.
- *Mitigation:* This response means keeping the risk under control. In other words, it helps the project manager and team to reduce the possibility and/or impact of a risk on the project. For instance, developing prototypes and performing much more tests are important mitigation responses for a new product development (NPD) project. Also, contingency plans are very useful to mitigate possible risks.
- *Transfer:* This response consists of sharing risk with third party. There are several ways such as insurance, warranties, contracts and etc.

Kernzer also proposes four response actions for opportunities; "acceptance, enhance, exploit and share". In contrast with the risk responses, these ones try to increase the possibility of occurrence of opportunities (enhance), having a good part in the market (exploit) and maximizing benefits with a partner (share).

Monitoring & Controlling Risks

This process follows and reviews the effectiveness of risk responses. Thus, both new risk response strategies can be developed and current strategies can be updated. Kernzer proposes some techniques prominent for monitoring and control process [4]:

- *Earned Value (EV):* That technique is used to determine cost, schedule and technical performance of risk strategies. The clause 4.2.4 of this thesis also handles earned value management system and its application to Stage-gate methodology in details.
- *Program Metrics:* That technique is utilized to check corrective actions which are created after evaluating of the risk management process.
- *Schedule Performance Monitoring:* That technique tracks schedule performance of the project as effected by risk response actions.
- *Technical Performance Measurement (TPM):* That technique is a product design review that monitors technical performance of product design as affected by risk response actions.

4.2.2.2 Implementation of Risk Management to Stage-Gate Process

Generally, only financial and scheduling risk management has been performed in the previous years. Project budgets were increased to mitigate financial risk. Furthermore, more and more time was added to the schedules to mitigate scheduling risk. In fact, technical risk management has become critical since 1990's [8]. Especially for NPD projects, technical risk management is very important because, so many unexpected problems can be emerged at different stages of the projects. Risks cause schedule or cost overruns or can affect project quality or the ability to deliver on custom requirements. Some companies declare a new product to the customers and form a contract that includes budget and schedule for this NPD project. If a critic technical problem emerges at any stage of the project and if the company does not have a clear contingency plan to mitigate any kind of technical risk, that would cause a crisis between customer and supplier. Because the supplier needs to add more time to the schedule and/or demands more budget to give a solution to solve technical problem. If a supplier works for a third-world client who has not developed their own systems yet, one hundred percent of the risk belongs to the supplier, especially if the projects get more complex just as presented in the Figure 4.18 [8]:

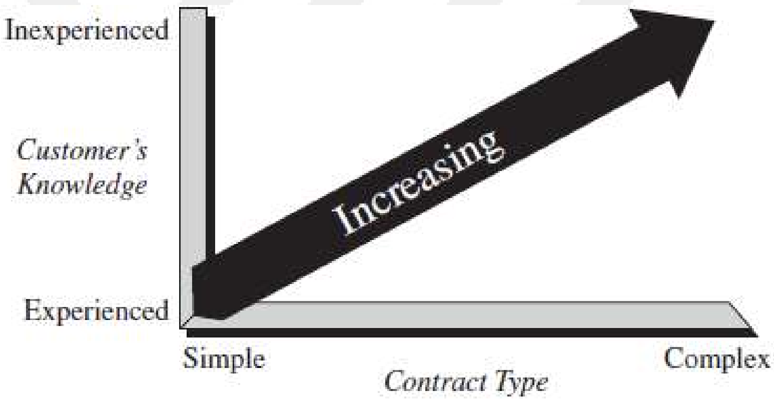


Figure 4.18 Future Risks

For an NPD project which is managed with integrated project management methodology, risk management is an important parameter to finalize the project within planned budget and schedule limits and with high product quality. All the risks are identified at Stage-0. Even a decision tree can be built to decide which way the project should be tended, if needed. However, new risks will arise depending on new tasks or unexpected problems in a stage. Also, each change on the project requirements creates change gates and that causes to have new risks. Also a risk response plan should be developed at Stage-0 to mitigate the risks during the project. This plan is updated as new risks are added into the risk pool so long as stages are proceeded.

4.2.3 Change Management

An introduction to change management concept is made in the clause 2.2.2 of this thesis. As it is mentioned, change management methodology is very important especially for NPD projects. In the thesis, a combined project management methodology which consists of Stage-gate methodology is proposed for management an NPD project. NPD projects can have so many uncertain outcomes after each stage. Hence, these uncertainties are needed to be managed by a methodology called as change management.

4.2.3.1 Change Management Steps

In order to implement a successful change management, ten steps can be applied [32]. These steps present the essential keys for project success.

Step-1 Understanding of Change

The key for the success is being prepared for a change that comes out from a stage review. Changes can occur in many forms such as technical, financial and environmental (competition, technology, and customer preferences).

Changes can be categorized as continuous and discontinuous changes. The targets of continuous changes are adjusting processes and improving current products consistently. Discontinuous changes consist of major changes in technology, process and project team.

This thesis only focuses on discontinuous changes that can merge during the stages of an NPD project. Project manager and its team should be dynamic, flexible and agile to give quick responses to these changes.

Step-2 Assessment of the Impact of Change

According to the impact of a change, project manager can make a prioritization and change plan as making an evaluation. Hence, the sources of the project (money, people and time) can be utilized effectively.

Step-3 Assemble a Change Management Team

Since the combined methodology includes change management method in the scope of this thesis, project management team also can be assigned as a change management team. Some companies set a change management team as a support to project management team.

The starting point is to identify the roles and tasks in order to execute the change strategy. Then, the tasks are assigned to the right people in the team. Assignment process is very important for the effectiveness of the team and project success.

Step-4 Building a Vision for Change

From a widest point of view, a company needs a vision of change to organize people within a roadmap in case of a major change is required. This change both can be an external environmental change that aims to build a great company and also it can be an internal change that is needed to improve the current situation. Figure 4.19 illustrates the change factors which are handled within the scope of change vision.

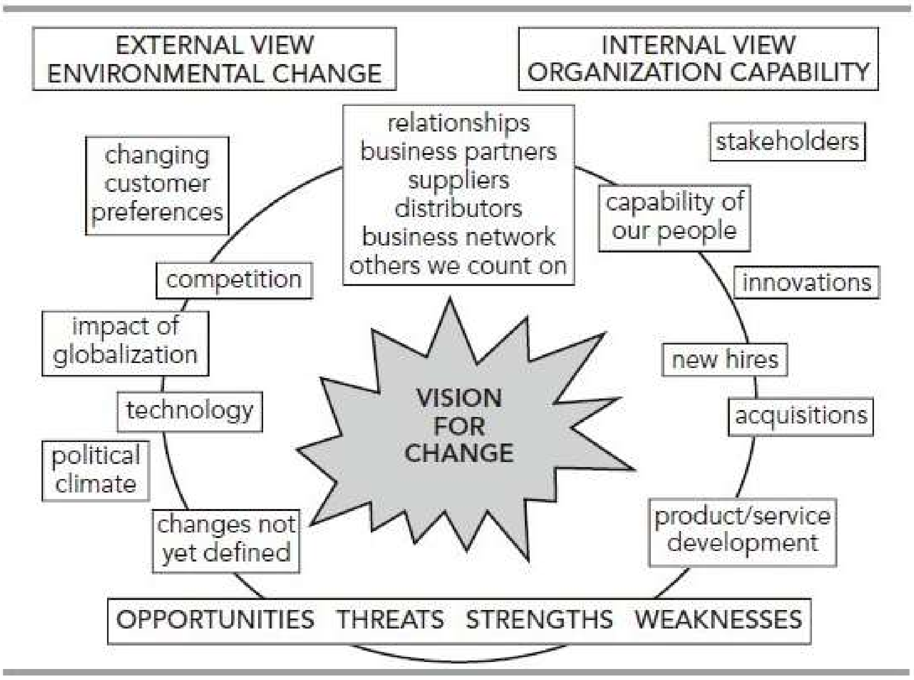


Figure 4.19 Change Factors

Step-5 Building a Change Strategy

A change strategy is defined as how to make things happen with the resources available. The change strategy addresses the vision for change and what it will do for the organization.

The change strategy is broken down into three component areas. These areas are utilized to build a roadmap for the change strategy.

- *Strategic:* This is the overall plan as an idea. Additionally, it includes what the organization hopes to achieve.
- *Operational:* This is the process of identifying what will be done in each area.
- *Tactical:* This is the process of determining the specific tasks to be completed. It should include functional areas, names assigned, and deadlines to be met.

Step-6 Winning Support

In case of making decision on a change, the project manager can have a level of support or resistance by the members of project team or stakeholders. That also helps building a change strategy.

There are supporters, detractors and undecided stakeholders that evaluate the change. By identifying the various groups, and in some cases subgroups, which can affect the change process, the project manager can determine their potential concerns and how they might see the change affecting them and the project status. Different points of view also help to understand better how much important the change is for the project success. Moreover by being open and giving people a chance to voice their concerns, the project manager builds his credibility.

Step-7 Effective Communication

One of the most important skills of a project manager is the ability to communicate. Daily scrum meetings are good example for effective communication.

A communication strategy should be built for any major change initiative. The strategy should include all the appropriate stakeholders. Popular communication channels are face-to-face (meetings), e-mail sending/receiving, phone calls, teleconferences and social media.

Step-8 Overcoming Challenges

During a change initiative, some challenges come in a number of ways and from a number of sources. Challenges can be stakeholders who resist changing, lack of resources, competitors that develop new technologies which threaten the market share and ineligible team members to change.

In order to overcome the challenges, the project manager should always remember to utilize the change vision to help people understand the reason behind and goal for the change.

Step-9 Measuring Success

It is very important to measure and review the change process in order to be sure whether the project team is in the right way or not. The prominent measurement parameters are listed below:

- *Budget:* Judging the amount of money spent for the change and evaluating total spending is under or over the budget.
- *Time:* Judging if the change affects the project schedule in negative way or not.
- *People:* Judging if the project team members' contributions are sufficient or additional team members are needed to manage the changes successfully.
- *Resources:* Judging the effectiveness of using available sources.
- *Competition:* Judging the level of competition after the implementation of change.

Step-10 Reviewing Lessons Learned

Reviewing the lessons learned during a change process is important for the project manager and its team. Managers are encouraged to take the time to consider how the outcome of one change initiative will affect their future behavior in the organization, especially in change management. This knowhow helps to develop exhaustive contingency plans for the possible changes in the future.

4.2.3.2 Implementation of Change Management to Stage-Gate Process

For an NPD project which is managed with integrated project management methodology proposed by this thesis, also change management is crucial to finalize the project within planned budget and schedule limits and with high product quality that meets the requirements of the customers in the market.

This thesis proposes a new approach for change management to implement this method within Stage-gate methodology. The new approach suggests adding "change gates" within a six stages-six gates model that is generally used for NPD projects. Figure 4.20 presents the new Stage-gate model which contains change gates inside:

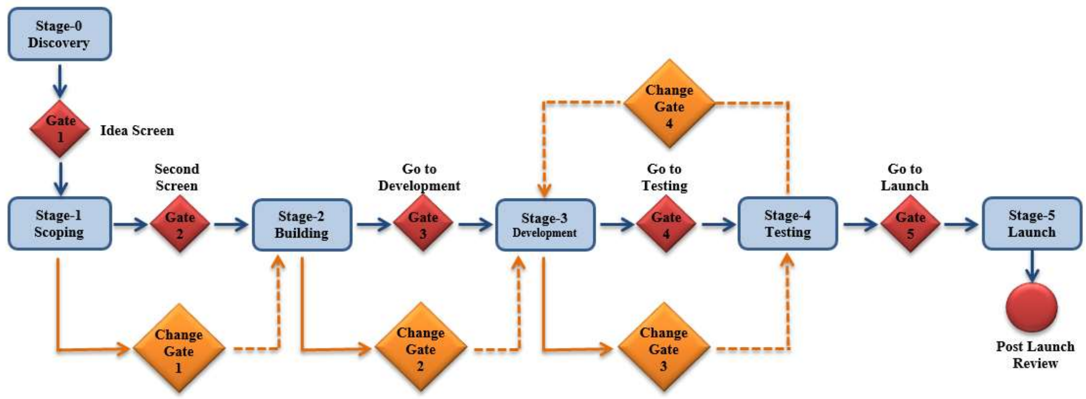


Figure 4.20 Stage-Gate model integrated with change gates

There are four change gates which are integrated into the stage-gate model. Ideally, these change gates can be managed by a small change team that is built only for following change initiatives. Main gates are utilized to review unchanged scopes of the project. The change gates give a chance to project team (or change team) to review only the changing project scopes within a specific schedule. In case the evaluation of change initiatives is negative, the change initiative is killed and the gate is closed. Hence, the natural progress of the project is not affected negatively.

First change gate can be placed after Stage-1. As it is mentioned in the clause 3.5.1, Stage-1 consists of a preliminary market assessment and technical assessment. In conclusion, both financial and business analyses are presented as deliverables to Gate 2. If there exists a change requirement according to market sharing or any new technology development, Change Gate-1 is built. The changes which are agreed on implementing are reviewed in the first change gate. If the review is positive, the deliverables are transferred to Stage-2. If the review is negative, the changes are killed. This phenomenon is same for all change gates. However, if a change is highly major and if it directly affects the whole project plan, the related change gate can be integrated with the main gate. As a change requirement occurs during testing stage, this change should be implemented in the development stage. Hence, a reverse feedback is given to the development stage. This change is evaluated in Gate-3 and then it is tested in the testing stage. Finally, if the results are positive, the change is evaluated again in the Change Gate-4. If the review is positive, launch stage can be started.

In fact, the change management interacts with the agile project management methodology. As it is mentioned in the clause 3.3.2, the scrum methodology is one of the agile management methodologies. The scrum methodology has a main target of maximizing project team's ability for giving agile responses to customer needs which change frequently. As a proposal of this thesis, the change team can be managed by a scrum master who works under the project manager. The scrum master arranges daily scum meetings in which the current situation of the change process is followed. The deliverables from each scrum meeting are collected into one sprint. The duration of each sprint is determined depending on the schedule of change process and timing of a change gate. Thus, each change is tracked by the change team and scrum master strictly. The scrum master reports the change process to the project manager.

The Figure 4.20 demonstrates the ideal presentation of Stage-Gate method with four change gates. From more flexible point of view, the number of change gates can be more than one before a main gate depending on the timing of the sprints. As a conclusion, when the change management with an agile point of view is combined with the stage-gate methodology, the project is managed effectively.

4.2.4 Earned Value Management (EVM)

EVM is a management technique that is used for measuring the performance of the project in terms of technical, cost and schedule targets. In project management history, this term has been called under different titles such as, Planned Value of Work Accomplished (PVWA), the Budgeted Costs of Work Performed (BCWP), the Cost/Schedule Control Systems Criteria (C/SCSC), the Cost/Schedule Planning Control Specification (C/SPCS), Program Evaluation and Review Technique (PERT)/costs and so on [30].

Earned value provides project managers with a type of "early-warning" buzzer that gives them a chance to take the necessary corrective action in the earlier stages of the project. In order to measure project performance, Kernzer defines three basic terms [4];

- Budgeted cost for work scheduled (BCWS) is the budgeted amount of cost for work scheduled to be accomplished plus the amount or level of effort or apportioned effort scheduled to be accomplished in a given time period.
- Budgeted cost for work performed (BCWP) is the budgeted amount of cost for completed work plus budgeted for level of effort or apportioned effort activity completed within a given time period.
- Actual cost for work performed (ACWP) is the amount reported as actually expended in completing the work accomplished within a given time period.

These variables are defined with different names in PMBOK® Guide [1]. BCWS refers to PV (Planned Value); BCWP refers to EV (Earned Value) and ACWP refers to AC (Actual Cost).

Project Management Institute (PMI) expresses that the project budget and the integrated master schedule are key elements to develop the performance measurement baseline (PMB). PMB is established through a process of selecting and applying an appropriate performance measurement method to each work package [33]. In other words, PMB is used to compare planned performance with actual performance to determine project status. The information in the PMB must be in sufficient detail to ensure that actual results are properly monitored, recorded, and compared against the planned results. The performance measurement baseline (PMB) must include, but is not limited to the following elements:

- Schedule start and completion dates for each work package and planning package in the WBS
- Budget for each work package and planning package, and its time-phased distribution, decomposed by the resources allocated
- Time-phased distribution of the quantities of the resources allocated to each work package and planning package

4.2.4.1 The Calculation of the Project Performance

According to PMI, earned value management relies on four key data point: Planned Value (PV), Earned Value (EV), Actual Cost (AC) and Budget at Completion (BAC). Figure 4.21 presents the summary of those parameters in one graph [33]:

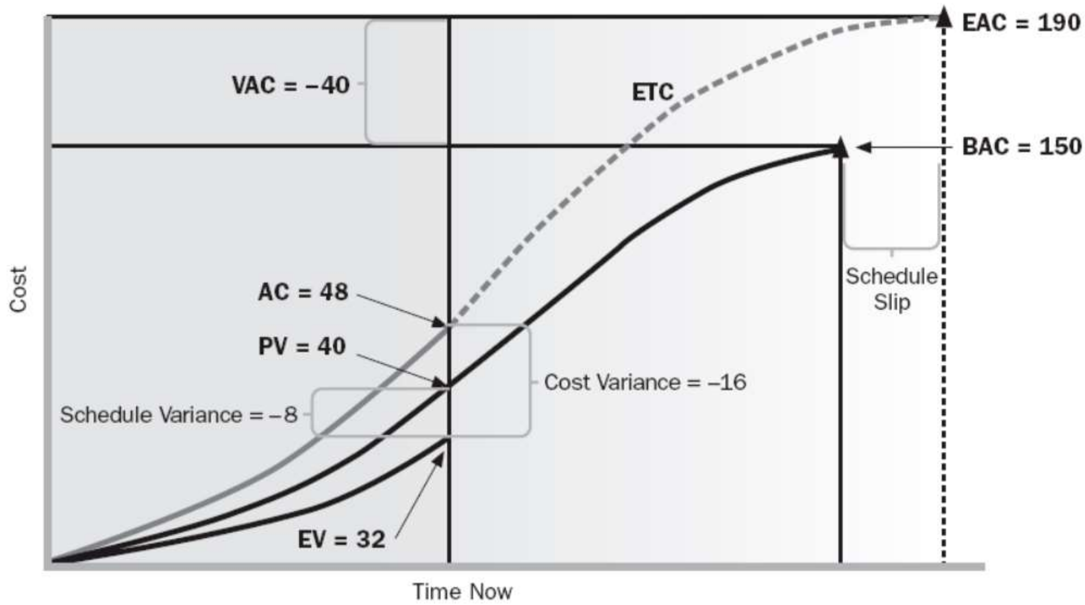


Figure 4.21 Graphic View of EVM Data

Figure 4.21 shows the earned value at “time now” and indicates that less work than planned has been accomplished. Moreover it shows the actual cost at “time now” and indicates that the organization has spent more than it planned to spend in order to achieve the work performed to date [33]. The graph shows that both PV and AC spent for achieving the planned work are very important parameters to analyze the project successfully.

In order to analyze the data, PMI proposes to calculate schedule variance (SV), cost variance (CV), cost performance index (CPI) and schedule performance index (SPI) values by the formulas in Figure 4.22 [33]. The Figure 4.22 also includes estimate at completion (EAC) and budget at completion (BAC) calculations.

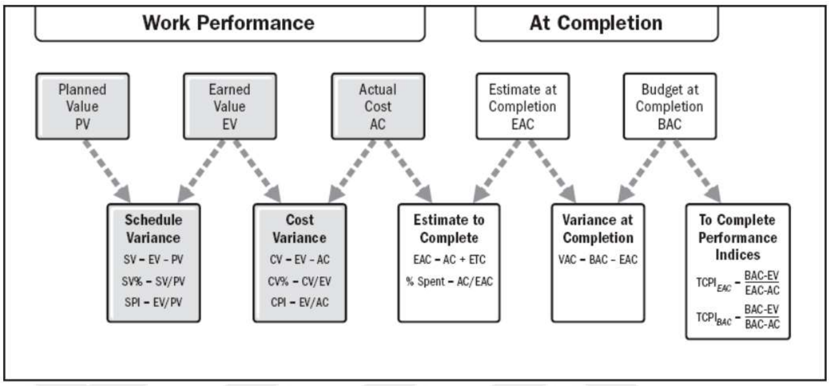


Figure 4.22 Basic EVM Variance and Index Calculations

Hence for the graph in Figure 4.21, the CPI and SPI calculations can be made as below:

Cost Performance Index (CPI): EV / AC = $32/$48 = 0.667

Schedule Performance Index (SPI): EV / PV = $32/$40 = 0.80

The result shows that even if CPI and SPI has a correlation between each other's relating to EV, both them should be calculated separately because actual cost spent by project team can be different from planned value accomplished. Figure 4.23 shows what the EVM performance measures indicate about a project with regard to its planned work schedule and resource budget [33]:

Performance Measures		Schedule		
		SV > 0 & SPI > 1.0	SV = 0 & SPI = 1.0	SV < 0 & SPI < 1.0
Cost	CV > 0 & CPI > 1.0	Ahead of schedule under budget	On schedule under budget	Behind schedule under budget
	CV = 0 & CPI = 1.0	Ahead of schedule on budget	On schedule on budget	Behind schedule on budget
	CV < 0 & CPI < 1.0	Ahead of schedule over budget	On schedule over budget	Behind schedule over budget

Figure 4.23 Basic EVM Performance Measures

The cost and schedule performance indices can be used to statistically forecast the final required funds needed to complete the project. The general formula which is shown below can be used to calculate final require fund (estimate at completion value). This formula expresses that future cost performance will be influenced additionally by past schedule performance [33]:

Estimate at Completion (EAC) = AC + [(BAC − EV) / (CPI × SPI)]
EAC = $48 + [($150 − $32) / (0.667 × 0.80)] = $269

By the assumption of that the future cost performance will be the same as all past cost performance (no schedule performance impact), SPI value will equal to “1” and the formula is converted to [33]:

Estimate at Completion (EAC) = AC + [(BAC−EV)/CPI] = BAC / CPI
EAC = $48 + [($150-$32)/0.667] = $150 / 0.667 = $225

In another source, Kernzer also highlights the importance of measuring project performance by the cost and schedule parameters [4]. Project performance is calculated by the help of the variables in the special formulas of variances. There are two important variance parameters for a project. One is cost variance (CV) and the other one is schedule variance (SV). According to Kernzer, CV and SV must be considered together throughout the project to make a realistic review of the performance [4]. Because, cost variance compares deviations only from the budget; does not compare work scheduled and work completed. On the other hand, schedule variance compares only planned and actual performance and does not give data on the cost.

Cost Variance calculation;

CV = EV - AC

CV % = CV / EV

If the CV is negative, that shows a cost-overrun condition.

Schedule Variance calculation;

SV = EV - PV

SV % = SV / PV

If the SV is negative, that shows a behind-schedule condition.

Addition to cost and schedule variances, the efficiency of the work completed can be calculated. The formulas used to calculate the performance are presented below:

Cost Performance Index (CPI): EV / AC

If CPI = 1, cost performance is perfect.

Schedule Performance Index (SPI): EV / PV

If SPI = 1, schedule performance is perfect.

In Figure 4.24, project variance projection is demonstrated [4]. It shows the time-phased cost variances for a program requiring research and development, qualification, and production phases. Since the risk should decrease as time goes on, the variance boundaries are reduced.

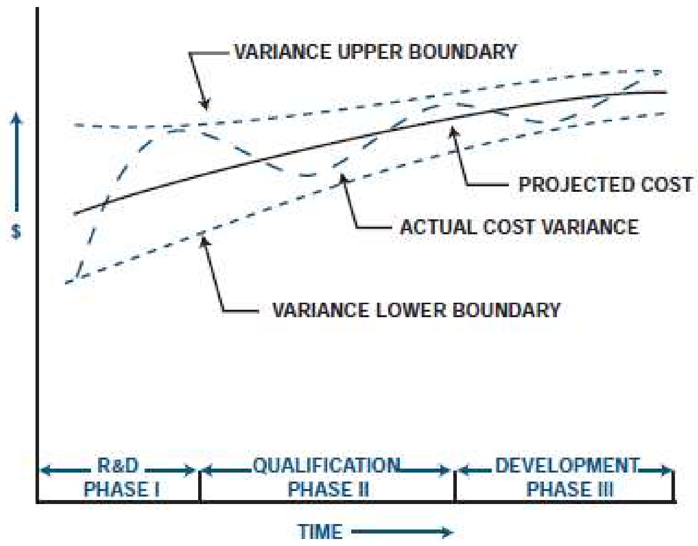


Figure 4.24 Project variance projection

The cost and schedule performance index is most often used for trend analysis as shown in Figure 4.25 [4]. Companies use three-month, four-month, or six-month moving averages to predict trends. Trend analysis provides an early warning system and allows the managers to take any corrective actions.

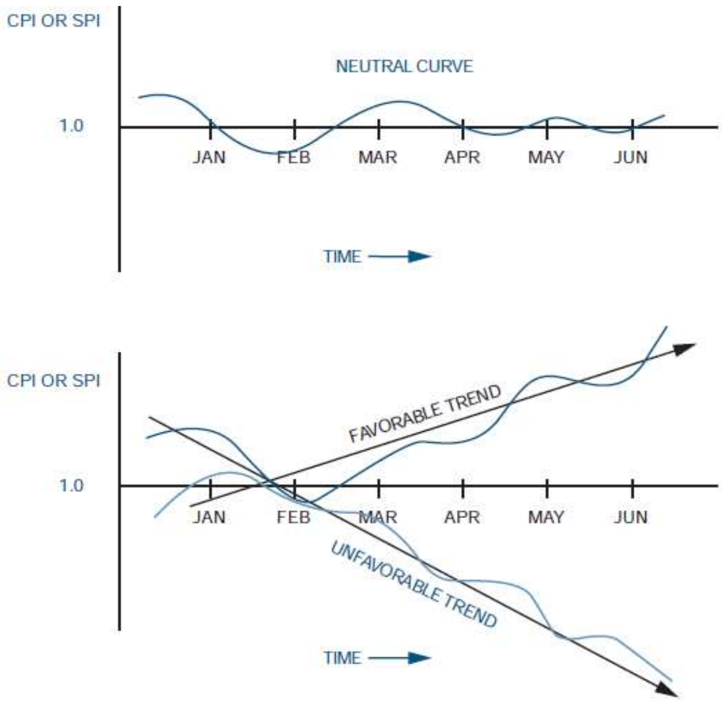


Figure 4.25 The performance index

Earned Value Management (EVM) brings a new perspective to traditional cost management. In the following example, EVM is compared with traditional cost management in terms of point of view to cost performance of a project. [30].

We can take a twelve-month project in hand that its expenditure is expected as $1.000.000. Cost performance curve of this project is illustrated in Figure 4.26. The curve shows the schedule versus actual costs for a Traditional Cost Management approach.

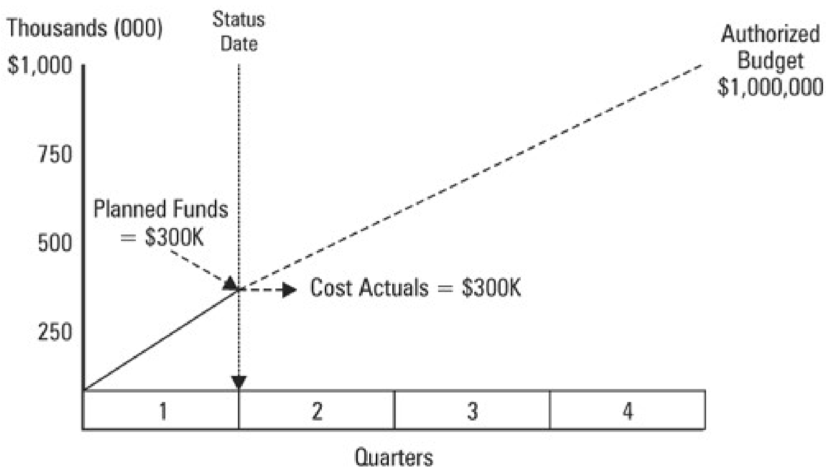


Figure 4.26 Cost performance trend for traditional cost management

From traditional point of view, financial performance of the project seems perfect. The planned funds were $300 K for the first quarter and $300 K was spent. But, this is not a real project performance. Because, there is no information about what percentage of the planned work has been completed for the first quarter. In other words, the cost variance and schedule variance should be evaluated together for the true project performance review.

There is a new third parameter in cost performance curve for earned value management. It is called as "Earned Value". Moreover, the amount forecasted to be spent at the end of the first quarter is now called as "Planned Value." Earned value seems $200 K at the end of first quarter in Figure 4.27. This result presents that there is a behind-schedule condition at the moment:

$SV = EV - PV = \$200K - \$300K = - \$100K$

Also, the result reflects that there is a cost-overrun condition.

$CV = EV - AC = \$200K - \$300K = - \$100K$

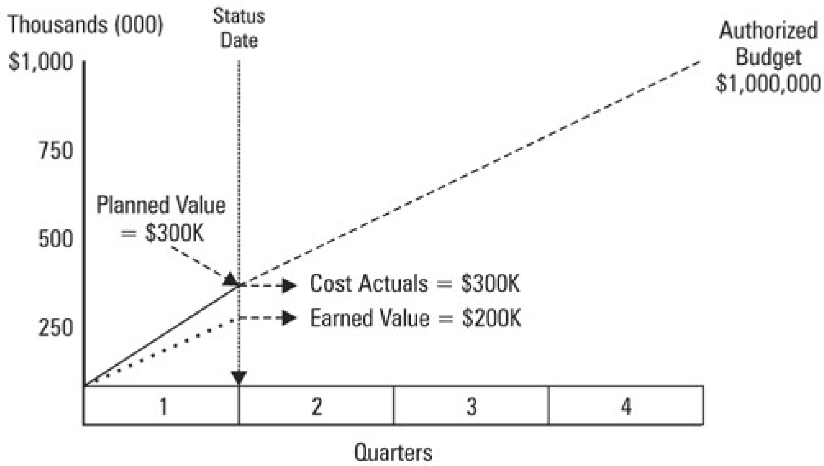


Figure 4.27 Cost performance trend for earned value management

The same example can be reviewed with cost and schedule performance indices. But this time, the illustration of cost and schedule curve is different. The curve is converted to a bar display in Figure 4.28 [30].

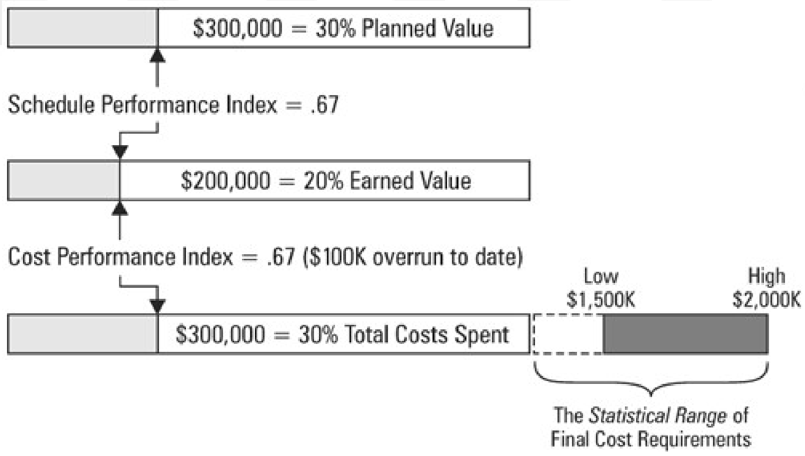


Figure 4.28 Performance indices bars

Cost and schedule conditions are defined with efficiency factors in this approach. There are two questions which are needed to be answered for the future of the project.

The first one is that how long will the project take to complete all of the work? In order to reply this question, SPI should be calculated. For Schedule Performance Index (SPI) calculation, $200 K earned value is divided to $300 K planned work.

Schedule Performance Index (SPI): EV / PV = $200 K / $300 K = 0.67

Therefore, the efficiency factor is 0.67. It is an early alarm that shows the project cannot be completed within target schedule unless additional resources (such as more people, funds and etc.) are added.

The second one is that how much will the project require completing all of the work? In order to reply this question, CPI should be calculated. For Cost Performance Index (CPI) calculation, $200 K earned value is divided to $300 K actual cost.

Cost Performance Index (CPI): EV / AC = $200 K / $300 K = 0.67

Therefore, the efficiency factor is 0.67. In other words, for every project dollar that was spent, only sixty-seven cents in physical work was accomplished. The CPI can be used by itself or in conjunction with the SPI to forecast a statistical range of estimated final costs to complete the project.

As a general review, both the cost and schedule performance indices can be used to statistically forecast the final required funds needed to complete the project. In third bar display of Figure 3.5, the statistical range of final cost requirements is shown by considering the situation of the project for the first quarter. If the total budgeted funds of $1.000.000 are divided to the amount by CPI factor of .67, statistically forecast that nearly $1.500.000 would be needed to complete the project. The second approach is a high-end statistical method that consists of both SPI and CPI by multiplying them each other. The result is calculated as; "0.67 x 0.67 = 0.4489". By this method, new forecast to complete the project is found as $2.000.000 like below:

Forecast Budget = AC + [(BAC − EV) / (CPI × SPI)]
EAC = $300 K + [($1000 K − $200 K) / (0.67 × 0.67)] = $2 M

4.2.4.2 Implementation of Earned Value Management to Stage-Gate Process

As it is mentioned, earned value management is crucial to review real performance of the project. It is an early warning system which notifies to the project manager that the project is under risk depending on budget or schedule overrun. For an NPD project which is managed with integrated project management methodology includes stage-gate, risk management and change management methodologies, earned value management evaluates the project performance in terms of planned budget and schedule and also it assesses the effectiveness of risk management and change management methods which support Stage-gate management system.

The product specifications are clarified in the Stage-2 and the project schedule and the project budget can also be determined in this stage. Earned value management judges the project performance during the life cycle of a project. In order to check the project performance strictly, it is proposed to calculate “cost performance index (CPI)” and “schedule performance index (SPI)” within each gate as starting from Gate-2. Furthermore, the effect of the changes which are discussed in the change gates also should be considered while CPI and SPI calculations are made.

After CPI and SPI calculations are made, the performance of the project can be reviewed by the project manager. The forecast is calculated and this value is compared with the budgeted funds specified at the beginning of the project. If the forecast and the budgeted fund are in the similar level, the project performance is in good state. If extra timing or more budget is needed to finish the project within planned time and budget -in other words if the forecast is higher than planned budget- the project manager should take action to accelerate the completion time of the tasks within a stage.

Earned value management (EVM) supports the stage-gate methodology to measure the project performance after each stage. Hence, the project manager has enough time to minimize the risk of project delay or cost overrun. EVM contributes the success of a project greatly.

CHAPTER V

DISCUSSION

Generally, the management of a new product development project is challenging. There are so many new parameters and unexpected cases which are emerged throughout the progress of the project. The research shows that today the big companies such as Nortel, Ericsson and Johnsons Controls Automotive use integrated project management methodologies just as shown in Figure 2.1. Furthermore, it is seen that the stage-gate methodology is applicable for NPD projects. Cooper et al. (2002) reveals three versions of stage-gate process which are optimized regarding the level of risk for the project. These versions are significant customer request process, fast track process and full 5-stage process. Valeri et al. (2004) reveals a new quality gate approach which is called "flexible process-oriented approach that proposes an overlap concept (i.e., tasks belonging next phase can start before the previous phase finishes and changes adaptation within gates. Pons (2008) notices that stage-gate methodology is a popular approach to manage uncertainties within an NPD project but not enough by itself. In other words, he comes up with an integration of a method with stage-gate methodology for a better management system. Broum et al. (2011) presents a new way of reducing the cost of innovation by integrating a value analysis to the stage-gate process. The combination of value analysis and stage gate process creates a new model that can reduce the costs of innovative product to the competitive level for the market. As a result, it seems that there is a necessity of integrated methodologies which increases chronologically.

In the thesis, an optimum integrated project management methodology that is applicable to a new product development project is proposed. The integrated methodology consists of schedule-oriented stage-gate, risk management, change management and earned value management methodologies. In order to evaluate the benefits of the integrated methodology, a company called as "X" which produces new products for the customers is handled. The old methodology of the X Company is presented and then the benefits, which are gained after the new project management system setup is applied to the company, are discussed. As a result, it has been seen that the benefits verify the validity of the proposed integrated management methodology.

X company introduces new products for the customers. However, the company has a traditional project management method. As the company culture and the progress of the projects are checked, the management system seems like a waterfall model. Figure 3.2 presents the waterfall model. The project phases are progressed without re-visiting the previous phase in general. Therefore, the progress is very fast but also quiet risky because of the lack of adaptability to the changes or fatal problems which may occur during the phases. On the other hand, there is no systematical risk management application in the company. Therefore, contingency plans cannot be prepared at the beginning of the project. Consequently, if a possible risk arises, there is no plan to overcome that. In that vein, that issue causes an overflow in cost and schedule. Throughout the project, only schedule is followed by the project team but there is not any schedule or cost performance measurement system. When all these parameters are brought together, it can be claimed that nearly none of the projects cannot be finished within planned time and planned budget.

The integrated methodology has been being applied for an NPD project which has been planned as a 12-month term project. In the thesis, the first half of the project (six month period) has been presented. First of all, X Company prepares a time chart and designates timing of each stage and gate. After that, this time chart is embedded into MS Project program as a detailed schedule. The time chart is illustrated below:

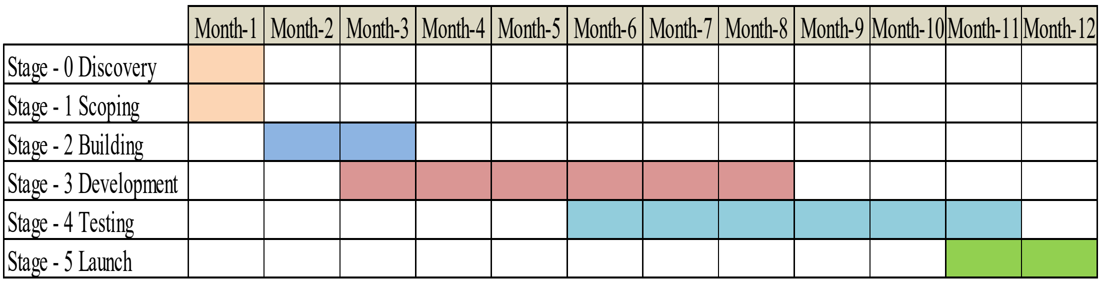


Figure 5.1 NPD project time chart of “X Company”

As expected, there exists overlapping between stages in order to keep them flexible during whole project timing.

A risk management plan is prepared at Stage-0 by X Company. Possible risks are identified and a contingency action is specified as a risk response plan for each risk item. The list of the possible risks is updated as the stages proceed. One of the actions within contingency plan is to develop more than one prototype of the specific product. These prototypes have all of the features of the new product but they are equipped with a few different parts to prevent any possible risks. In other words, instead of testing a specific product only, many different prototypes are tested simultaneously. Hence, if the project team faces any problems with one type of prototype at the performance tests, there are different alternatives in their hand that provides no delay in the project schedule. If there is no "risk management system" for an NPD project, any kinds of problem cause delays in the schedule. Furthermore, spending more money to overcome the problem may cause budget exceeding.

The project schedule and budget are specified at the beginning of the project. The authorized budget of this NPD project is €1.5 million and the schedule to finish the project is twelve months. The integrated project management methodology gives the project team an opportunity of evaluating the schedule and the cost by measuring performance indexes continuously with an earned value management system. Hence, the project team has an early warning alarm to make some decisions on accelerating the process and/or cost optimization. X Company plans to check the cost and schedule performance indexes for the NPD project for every stages starting from Stage-2. Surely for longer stages such as development, SPI and CPI are calculated a few times during the stage period. The calculated values are discussed in the gates or in the daily scrum and monthly sprint meetings. The earned value (EV), planned value (PV) and actual cost (AC) information are illustrated as a graph in Figure 5.2. Planned value is the project budget and it is reflected with blue line that is distributed within stages through twelve months. Red line shows the trend of earned value. The first SPI and CPI calculations are made at the middle of Stage-2. In other words, the project performance of the first two-month period is reviewed. The first calculations are showed below:

Schedule Performance Index (SPI): EV / PV = €90 K / €100 K = 0.90

Cost Performance Index (CPI): EV / AC = €90 K / €100 K = 0.90

According to the results, it has been identified that the project cannot be completed within target schedule unless additional resources (such as more people, funds and etc.) are added or unless speeding up the work items. Moreover, the cost performance is also unsatisfied. For every one euro that is spent, ninety cents in physical work is gained. The final required funds needed to complete the project can be statistically forecasted:

$Estimate\ at\ Completion\ (EAC) = AC + [(BAC - EV) / (CPI \times SPI)] = €100\ K + [(€1.5M - €90K) / (0.9)^2 = €1.84\ M$

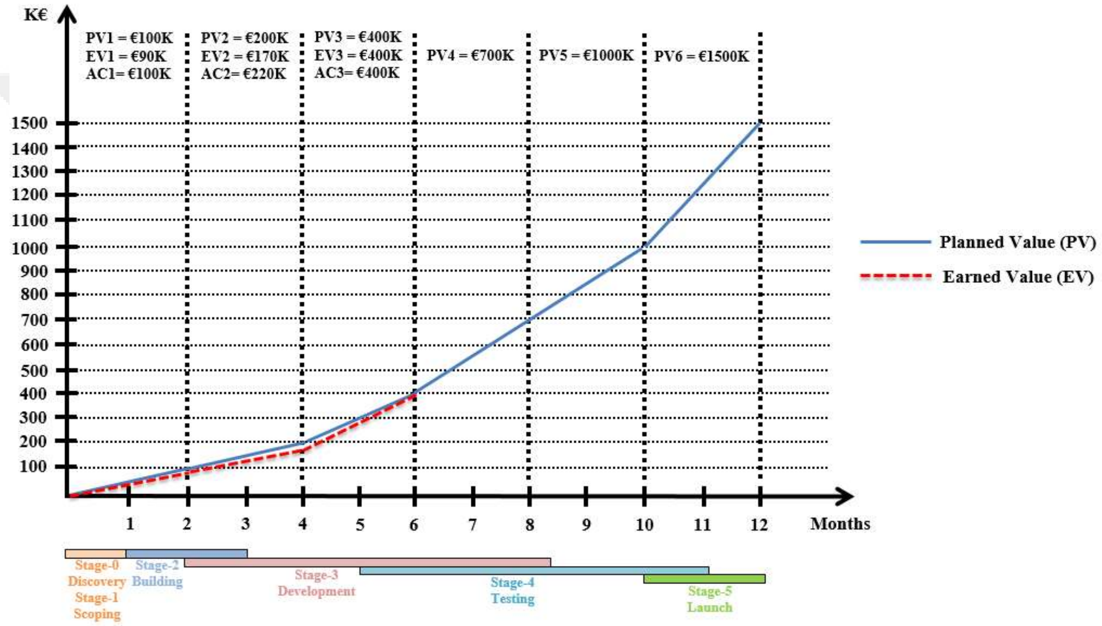


Figure 5.2 Earned value graph of the NPD project

X Company measures EV, PV and AC parameters for the second time after four months from starting. Then, SPI, CPI and new forecasted budget values are calculated like below:

$Schedule\ Performance\ Index\ (SPI): EV / PV = €170\ K / €200\ K = 0.85$

$Cost\ Performance\ Index\ (CPI): EV / AC = €170\ K / €220\ K = 0.77$

$Estimate\ at\ Completion\ (EAC) = AC + [(BAC - EV) / (CPI \times SPI)] = €220\ K + [(€1.5M - €170K) / (0.85 \times 0.77)] = €2.25\ M$

Figure 5.3 shows the whole details for the case study of "X project". The data is estimated for the first 2-month review. According to PV, EV and AC values after 2-month, it seems that since CPI and SPI values are lower than "1", EAC value is calculated as nearly € 1,84 M which is higher than BAC (budget of the project).

Estimate at Completion (EAC) = AC + [(BAC − EV) / (CPI × SPI)] = €100 K + [(€1.5M - €90K) / (0.9)² = €1.84 M

"X Project" Data	PV	EV	AC	% Comp.	CPI	SPI	BAC	EAC
Project Budget Baseline	-	-	-	-	-	-	**€ 1.500.000**	**€ 1.840.741**
Performance Review - 2 Month	**€ 100.000**	**€ 90.000**	**€ 100.000**	-	**0,9**	**0,9**	-	-
Stage-0	**€ 4.000**	**€ 4.000**	**€ 4.000**	**100%**	**1**	**1**		
Idea Generation	€ 1.000	€ 1.000	€ 1.000	100%	1	1		
Project Decision Tree	€ 1.000	€ 1.000	€ 1.000	100%	1	1		
Risk Response Plan Creation	€ 2.000	€ 2.000	€ 2.000	100%	1	1		
Gate-1	**€ 3.000**	**€ 3.000**	**€ 3.000**	**100%**	**1**	**1**		
Decision Tree Review	€ 1.000	€ 1.000	€ 1.000	100%	1	1		
Idea Screen	€ 1.000	€ 1.000	€ 1.000	100%	1	1		
Risk Response Plan Review	€ 1.000	€ 1.000	€ 1.000	100%	1	1		
Stage-1	**€ 10.000**	**€ 10.000**	**€ 10.000**	**100%**	**1**	**1**		
Technical Search	€ 2.000	€ 2.000	€ 2.000	100%	1	1		
Market Search	€ 4.000	€ 4.000	€ 4.000	100%	1	1		
Financial Analysis	€ 4.000	€ 4.000	€ 4.000	100%	1	1		
Change Gate-1	**€ 1.200**	**€ 1.200**	**€ 1.200**	**100%**	**1**	**1**		
Technical Change Assessment	€ 400	€ 400	€ 400	100%	1	1		
Market Change Assessment	€ 400	€ 400	€ 400	100%	1	1		
Change Go/Kill Decision	€ 400	€ 400	€ 400	100%	1	1		
Gate-2	**€ 1.800**	**€ 1.800**	**€ 1.800**	**100%**	**1**	**1**		
Financial Return Assessment	€ 600	€ 600	€ 600	100%	1	1		
Market Requirements Assessment	€ 600	€ 600	€ 600	100%	1	1		
Go/Kill Decision	€ 600	€ 600	€ 600	100%	1	1		
Stage-2	**€ 80.000**	**€ 70.000**	**€ 80.000**	**87.5%**	**0,875**	**0,875**		
Risk Response Plan Update	€ 2.000	€ 1.000	€ 2.000	50%	0,5	0,5		
Detailed Market Search	€ 2.000	€ 1.000	€ 2.000	50%	0,5	0,5		
Product Spec. Clarification	€ 1.000	€ 500	€ 1.000	50%	0,5	0,5		
Prototype Building	€ 75.000	€ 67.500	€ 75.000	90%	0,9	0,9		

Figure 5.3 Project Performance Review – 2 Month

Figure 5.4 shows the whole details for the case study of "X project" with the data estimated for the 4-month review. According to PV, EV and AC values after 4-

month, it seems that since CPI and SPI values are lower than "1" again, EAC value is calculated as nearly € 2.25 M which is much higher than BAC (budget of the project).

Estimate at Completion (EAC) = AC + [(BAC − EV) / (CPI × SPI)] = €220 K + [(€1.5M - €170K) / (0.85 x 0.77)] = €2.25 M

"X Project" Data	PV	EV	AC	% Comp.	CPI	SPI	BAC	EAC
Project Budget Baseline	-	-	-	-	-	-	€ 1.500.000	€ 2.248.297
Performance Review - 4 Month	€ 200.000	€ 169.867	€ 220.000	-	0,77	0,85	-	-
Additional Cost from 2-Month	-	-	€ 10.000	-	-	-	-	-
Prototype Design Revision	€ 10.000	€ 10.000	€ 20.000					
Stage-2	€ 10.000	€ 6.667	€ 10.000	66%	0,67	0,67		
Intro. of Product to Customers	€ 2.000	€ 1.333	€ 2.000	66%	0,67	0,67		
Prototype Testing	€ 2.000	€ 1.333	€ 2.000	66%	0,67	0,67		
Manufacturability Research	€ 2.000	€ 1.333	€ 2.000	66%	0,67	0,67		
Supply Chain Research	€ 2.000	€ 1.333	€ 2.000	66%	0,67	0,67		
Investment Cost Calculation	€ 2.000	€ 1.333	€ 2.000	66%	0,67	0,67		
Change Gate-2	€ 3.000	€ 1.500	€ 3.000	50%	0,50	0,50		
Product Spec. Rev. Assessment	€ 1.000	€ 500	€ 1.000	50%	0,50	0,50		
Prototype Revision Assessment	€ 1.000	€ 500	€ 1.000	50%	0,50	0,50		
Change Go/Kill Decision	€ 1.000	€ 500	€ 1.000	50%	0,50	0,50		
Gate-3	€ 4.000	€ 4.000	€ 4.000	100%	1	1		
Manufacturability Assessment	€ 1.000	€ 1.000	€ 1.000	100%	1	1		
Supply Chain Assessment	€ 1.000	€ 1.000	€ 1.000	100%	1	1		
Investment Cost Assessment	€ 1.000	€ 1.000	€ 1.000	100%	1	1		
Go/Kill Decision	€ 1.000	€ 1.000	€ 1.000	100%	1	1		
Stage-3	€ 73.000	€ 47.700	€ 73.000	100%	0,65	0,65		
3D Design	€ 4.000	€ 3.200	€ 4.000	80%	0,80	0,80		
New Prototype Building	€ 69.000	€ 44.500	€ 69.000	64%	0,64	0,64		

Figure 5.4 Project Performance Review – 4 Month

Surely, PV, AC and EV values are cumulative for 4-Month. For example, PV includes €100.000 from the first 2-Month period. After 4-Month, it totally reaches to € 200.000. In this 2nd 2-month period, the customer requests a revision on the design and this change request is reviewed in Change-2 by the change team and decides to make it. Therefore, there is a prototype design revision cost which is planned as € 10.000 but it costs € 20.000 at the end. This value is added to AC value. On the other hand, since there is a € 10.000 additional work (it is calculated as PV – EV = €100.000 - €90.000) which comes from 2-Month evaluation, it is also added to AC for 4-Month evaluation. Finally AC value reaches to € 220.000.

This is the second warning for the project manager. According to the results, the performance trend of the NPD project deteriorates. Since the project manager and the team are aware of the critical situation, the project manager creates some alternatives to minimize the cost and maximize the efficiency at work in order to keep SPI and CPI values very close to “1”. First of all, a new roadmap should be determined. According to first schedule, there are four more months for the development phase but in real case, both SPI and CPI parameters are behind the schedule. In other words, project manager and his team must make much more effort. Accordingly, the project manager draws a quick and transient roadmap that includes very precise actions and overcomes behind-schedule case. The roadmap consists of the actions below:

- ✓ Consultancy service from the technical university is rescheduled for an earlier time instead of waiting until Stage-4 testing phase. Development time is optimized according to technical trainee and extra time is gained.
- ✓ New test techniques are developed by means of technical consultancy. Moreover, test quantity and so the total test duration in Stage-4 are decreased. Hence, a few parts of the budget of Stage-4 could be shifted to Stage-3.
- ✓ Preliminary acceptance tests are scheduled within Stage-3. Also, these tests will accelerate final approval tests timing in Stage-4 regarding acquired experience in Stage-3. This action guarantees that SPI and CPI values are kept equal to “1” after Stage-4 as well.

Hence, the third measurement which is made at the end of the sixth month gives perfect results. Both SPI and CPI values are nearly equal to 1. The project is going on within an authorized budget and a planned schedule. At this point, one question mark should be answered. The consultant also costs to company. In other words, while the project manager tries to optimize the development process and timing of the tests, some money is spent for the consultancy service. But this cost is also considered while SPI and CPI calculations are made. The development timing and test duration optimizations tolerate the cost of the consultancy service as well.

Consequently, EVM warns the project manager to reorganize the project progress to rights. If there is no EVM system for an NPD project, schedule and budget cannot be kept under control in a well-organized way.

If there is any change necessity according to customer's request or quality improvement requirement that emerges regarding test results, change management team is active in X Company. The change process is tracked within a schedule. Daily scrum meetings are arranged until the change process is finished. The effect of the change on the CPI and SPI indexes is reviewed within change gates. If there is no change management system for an NPD project, the changes can cause cost and/or schedule overrun. As a summary, it has been seen that X Company applies the integrated methodology triumphantly. Briefly, this management system contributes to the success rate of an NPD project.

CHAPTER VI

CONCLUSION

The thesis handles the popular project management methodologies and the new product development terms separately. These terms are investigated in details throughout all chapters. The requirements of the new product development process are defined. As complying with these requirements, the optimum integrated project management methodology is created.

According to the research, it seems that waterfall methodology is an old-fashioned methodology and it more convenient for software development projects. Waterfall method does not have any iteration. However, iterations are very important for software development projects which are placed within an NPD project in order to be flexible to the customer's variable needs and unexpected cases. Therefore, this methodology is not proper for an NPD project management.

On the other hand, agile methodology is another popular one for software development projects. It is more advantageous in comparison with waterfall since agile approach is iterative. There are some revisions during the development and software is always adaptable to changes. Hence, it can give fast responses to customer's needs and requirements. However, this methodology is not adaptable to all phases of NPD projects directly. It can be used for software development part of an NPD project. Additionally, that method can be useful to manage changes in an NPD project. However, it falls short of managing the entire NPD project.

Lean Six Sigma is the other project management methodology that focuses on improving quality, reducing waste and increasing speed of the process. Hence, the quality of new product will be better and the cost and time saving will be achieved in production. Generally, Lean Six Sigma is a very useful methodology for process improvement projects and can be a part of overall NPD projects. Briefly, Lean Six Sigma is not a direct method to manage an entire NPD project. It can support NPD project management in terms of process improvement.

Stage-Gate methodology is very well-known NPD project management methodology that is commonly preferred in many companies around the world. This methodology divides the entire project to a series of stages and it reviews these stages by the help of gates. Gates are critical processes to give decisions of Go/Kill for the project by the help of decision criteria. This methodology is very useful to manage an NPD project but it needs the support of different management processes. So, some companies modify this method to adapt it their own culture.

According to the requirements of NPD projects, the thesis recommends the integrated project management methodology that consists of four management methods. The methods are illustrated in Figure 6.1:

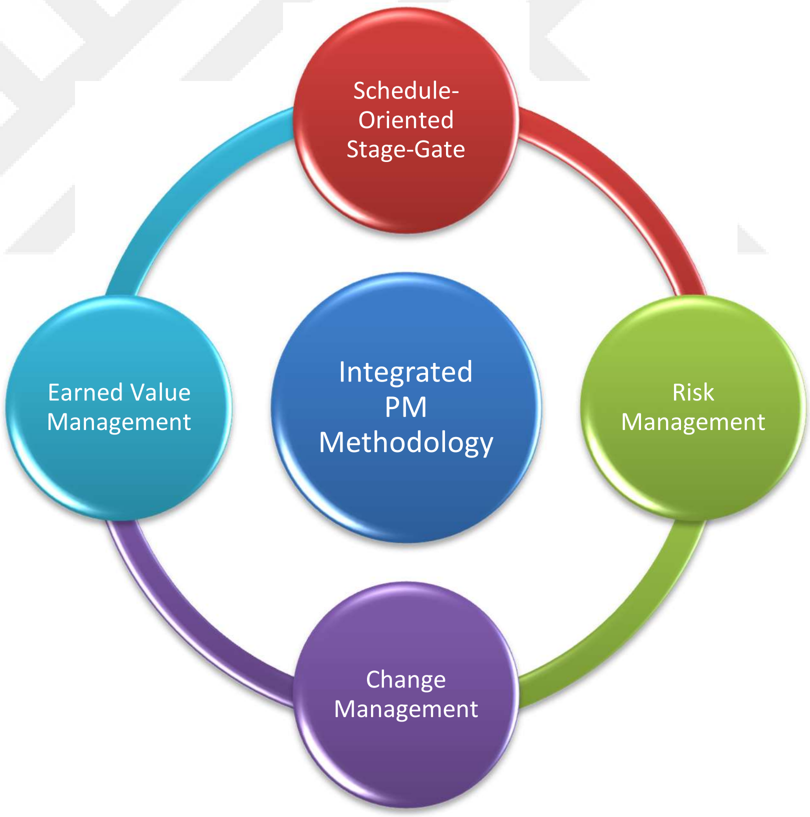


Figure 6.1 Integrated PM Methodology

Schedule-based stage-gate method proposes to build a total project schedule that includes stages, gates and change gates in MS project program. The entire schedule can be built in the Stage-2 since the product specifications are clarified in details at this stage. Stages and gates can be related to each other's through predecessors. If there are any changes or new requirements after a gate review, the project schedule is revised to add a change gate or new tasks within related stage. In this way, the project schedule is much more dynamic and the project is managed very effectively.

In the classical way, project budgets are increased to mitigate financial risk. Furthermore, more and more time is added to the schedules to mitigate scheduling risk. Effective risk management method prevents to spend extra budgets and extra time for an NPD project. For an NPD project which is managed with integrated project management methodology, risk management is an important parameter to finalize the project within planned budget and schedule limits and with high product quality. All possible risks are identified at Stage-0. However, new risks can occur depending on new tasks or unexpected problems in any stage. Also, each change on the project requirements creates change gates and that causes to have new risks. Hence, a risk response plan should be developed at Stage-0 to mitigate the risks during the project and this plan should be revised as new risks are added into the risk pool according to the changes so long as stages are proceeded.

The other management method that the thesis proposes to adapt to the stage-gate method is the change management. The new approach suggests adding "change gates" within a six stages-six gates model that is generally used for NPD projects. The scrum methodology has a main target of maximizing project team's ability for giving agile responses to customer needs which change frequently. As another proposal of this thesis, a change team which is managed by a scrum master can be assigned to these change gates. Thus, each change is tracked by the change team and scrum master strictly. The scrum master reports the change process to the project manager. As a conclusion, when the change management with an agile point of view is combined with the stage-gate methodology, the project is managed effectively and the risk of the overrun in cost or schedule depending on the changes is minimized.

Earned value management reviews the real performance of the project. It is an early warning system which notifies to the project manager that the project is under risk depending on budget or schedule overrun. For an NPD project, earned value management evaluates the project performance in terms of planned budget and schedule and also it assesses the effectiveness of risk management and change management methods which support stage-gate management system. Earned value management system uses CPI (cost performance index) and SPI (schedule performance index) calculations to be sure about the project success. Evaluation of CPI and SPI continuously gives an opportunity to the project manager to be had enough time to minimize the risk of project delay or cost overrun. Hence, this method contributes the success of a project greatly.

As a conclusion, the thesis reveals that the integrated project management methodology is the best practice for managing a new product development project. X Company applies this methodology successfully. New tools and more methodologies may be adapted into this methodology to have an improvement as a future study. As a future project, companies which will use my integrated project management methodology can build a PMO (Project Management Office) and adapt the methodology to the company's own culture. Hence, the project management methodology of the company is inspected periodically by PMO and the success rate of the projects is improved by years. As a future project for academicians and researchers, I propose them to develop a new index for earned value management; "technical performance index". Especially for innovative projects, technical performance of the project should be evaluated. For good progress of the project, schedule performance index and cost performance index are important parameters but technical performance measurement will be useful to understand that while cost and schedule are within targets but the product is not innovative enough. Even if cost and schedule performance measurements are helpful for better project management, the targets of the technical innovation should be guaranteed for project management excellence of an innovative product development project.

REFERENCES

[1] Project Management Institute (PMI), *A guide to the project management body of knowledge PMBOK® Guide,* 6th edition, Newtown Square, Pennsylvania (2017).

[2] http://en.wikipedia.org/wiki/Project#cite_note-PMH-5, (14.02.2014).

[3] Raydugin, Y., *Project Risk Management. Essential Methods for Project Teams and Decision Makers,* John Wiley and Sons Inc, Hoboken, New Jersey, (2013).

[4] Kerzner, H., *Project Management. A systems approach to planning, scheduling, and controlling*, 10th Edition, John Wiley and Sons Inc, Hoboken, New Jersey, (2009).

[5] Bimal P. Nepal, Om Prakash Yadav, Rajesh Solanki. *Improving the NPD Process by Applying Lean Principles: A Case Study*, Engineering Management Journal, 23 (3), 65-81, (2011).

[6] Ford, David N., and Durward K. Sobek, *"Adapting Real Options to New Product Development By Modeling the Second Toyota Paradox,"* IEEE Transactions on Engineering Management, 52 (2), 175-185, (2005).

[7] Pons, D., *Project Management for New Product Development*, Project Management Journal 39 (2), 82-97, (2008).

[8] Kerzner, H., *Project Management Best Practices: Achieving Global Excellence,* 3rd Edition, John Wiley and Sons Inc, Hoboken, New Jersey, (2014).

[9] Charvat, J., *Project Management Methodologies: Selecting, Implementing, and Supporting Methodologies and Processes for Projects*, John Wiley and Sons Inc, Hoboken, New Jersey, (2003).

[10] Stouffer D., Rachlin, S., *A Summary of First Practices and Lessons Learned in Information Technology Portfolio Management,* Chief Information Officer (CIO) Council, Washington, DC, p.7, (March 2002).

[11] Belliveau, P., Griffin, A. and Somermeyer, S., *The PDMA toolbook for new product development*, John Wiley and Sons Inc, New York, (2002).

[12] D. N. Prabhakar Murthy, Marvin Rausand, Trond Østerås, *Product Reliability: Specification and Performance,* Springer-Verlag London Limited, (2008).

[13] Hamid R., Parsaei, W. and Sullivan G., *Concurrent engineering: Contemporary issues and modern design tools*, Chapman & Hall, London, (1993).

[14] Jennifer A. Farris, Hilda C. Martínez León, *Lean Product Development Research: Current State and Future Directions,* Engineering Management Journal 23 (1), (2011).

[15] Sandro G. Valeri, Henrique Rozenfeld, *Improving the Flexibility of New Product Development (NPD) Through A New Quality Gate Approach*, Journal of Integrated Design and Process Science, 8 (3), 17-36, (2004).

[16] Cooper R.G., Edgett, S.J., *Maximizing Productivity in Product Innovation*, Research Technology Management, 51 (2), (2008).

[17] Cooper R.G., Edgett, S.J., Kleinschmidt E.J, *Optimizing the Stage-Gate® Process: What Best Practice Companies are Doing - Part Two*, Research Technology Management, 45 (5), (2002).

[18] Broum, T., Kopecky, M., Kleinova, J., *Enhancement of Stage-gate Process by Value Analysis,* Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, 22 (1), (2011).

[19] Royce, W., *Managing the Development of Large Software Systems*, Proceedings of IEEE WESCON, 328-338, (1970).

[20] Augustine S., *Managing Agile Projects,* Robert C. Martin Series, Prentice Hall, (2005).

[21] Augustine S., *Transitioning to Agile Project Management,* Agile Conference, (2007).

[22] Augustine S., *Introduction to Agile Project Management,* PMI Northern Italy Chapter, Milan, (2007).

[23] http://alistair.cockburn.us/Crystal+methodologies, (19.06.2008).

[24] Watkins J., *Agile Testing: How to Succeed in an Extreme Testing Environment,* Cambridge University Press, New York, (2009).

[25] Ilieva R., *Lean Six Sigma & Project Management,* PMI Bulgaria Chapter: PM Day 2013, (2013).

[26] Pojasek R.B., *Lean, Six Sigma, and the Systems Approach: Management Initiatives for Process Improvement,* Environmental Quality Management, 13 (2), (2003).

[27] Cooper R.G, *How Companies Are Reinventing Their Idea–to–Launch Methodologies,* Research Technology Management, 52 (2), 47-57, (2009).

[28] Cooper R.G., *Perspective: The Stage-Gate Idea-to-Launch Process – Update, What's New and NexGen Systems,* Journal of Product Innovation Management, 25 (3), 213-232, (2008).

[29] Cooper R.G., *Winning at New Products: Creating Value Through Innovation,* 5th Edition, Basic Books, New York, (2017).

[30] Fleming Q.W., Koppelman J.M., *Earned Value Project Management,* 2nd Edition, Project Management Institute, Newtown Square, Pennsylvania (2000).

[31] Office of Government Commerce (OGC), *Managing Successful Projects with PRINCE2™,* 5th edition, TSO, Norwich (2009).

[32] Vukotich G., *10 Steps to Successful Change Management,* ASTD Press (2011)

[33] Project Management Institute (PMI), *Practice Standard for Earned Value Management,* 2nd edition, Newtown Square, Pennsylvania (2011).

VITA

Mert Kıranç was born in Ödemiş, İzmir, on August 14, 1987. After completing his degree at Ödemiş Hulusi Uçaçelik Anatolian High School, İzmir, in 2005, he entered 9 Eylül University in İzmir, receiving the degree of Bachelor of Science in Electrical & Electronics Engineering in July, 2010. He has worked as R&D laboratory specialist engineer in Vestel Washing Machine Factory R&D department from September 2010 to December 2015. He has been working as R&D chief engineer in Vestel Dryer Machine Factory since January 2016.

Permanent Contact Address: mertkiranc@yandex.com ; mertkiranc@gmail.com