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Flaws in forecasting project cost and duration

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Abstract

In many projects final cost and duration exceed planned values. Which are the causes of these systematic underestimations?
Three possible explanations are given: technical explanations, psychological explanations, political-organizational explanations.
Technical mistakes in planning process could lead to inaccurate cost and duration planned values. Generally, looking at differences between planned and actual values, technical errors should cause an overall distribution around zero, but a poor risk management can lead to systematic errors.
Psychological factors may influence the values of forecasted cost and duration. Biases in mental make up of project promoters and forecasters can cause them to be overly optimistic about project outcomes.
Political and organizational pressures can lead to strategic misrepresentation. In situations of high pressure and competitiveness, promoters and forecasters intentionally accentuate positive aspects and intentionally underestimate costs and durations to get project approved.
A post-project review is proposed in order to improve promoters' and forecasters' awareness about possible flaws in cost and duration forecasts. Starting from a comparison between planned and final values, variations are evaluated and key factors that have influenced forecasting process are identified.

Abstract

Italian version

In molti progetti il costo finale e durata superano i valori previsti. Quali sono le cause di queste sottostime sistematiche?
Tre possibili spiegazioni vengono fornite da questo lavoro di tesi: spiegazioni tecniche, spiegazioni psicologiche, spiegazioni politico-aziendali.
Errori tecnici nel processo di pianificazione potrebbe portare a stime di costi e durate imprecisi. Generalmente, considerando le differenze tra i valori previsti ed effettivi, gli errori tecnici dovrebbero portare a una distribuzione casuale con media nulla, ma un'inadeguata gestione dei rischi potrebbe portare a commettere errori sistematici.
I fattori psicologici possono influenzare i valori di costo e durata prevista. La presenza di distorsioni ne processi mentali delle persone coinvolte nelle previsioni dei risultati del progetto possono causare una tendenza eccessivamente ottimistica.
Pressioni politiche e aziendali possono portare a rappresentazioni consapevolmente errate. In situazioni di forte pressione e competitività, le persone che hanno interesse in uno specifico progetto accentuano intenzionalmente gli aspetti positivi e sottostimano i costi e i tempi di durata per ottenere l'approvazione a eseguire il progetto stesso.
Un processo di post-project review viene proposto al fine di migliorare la consapevolezza riguardo possibili difetti nelle previsioni dei costi e delle durate. Partendo da un confronto tra i valori pianificati e quelli finali, le variazioni vengono valutate e vengono identificati i fattori chiave che hanno influenzato il processo di previsione.

Summary

Context

Managing projects means dealing with novelty and uncertain future scenarios. Every project is unique and represent a work that is sure to start, finish and be unrepeatable. However it is possible to define common functions of projects (Turner, 2009) and a general management process that is usually applied to most projects (Caron, 2009).
Focusing on the management process, it is possible to distinguish between two main phases of the project life-cycle: planning phase and execution phase. The first concerns scope definition and work planning and is related to the entire part of the project prior to the authorization to start work implementation (called sanction gate); this phase is typically divided into partial stages (figure 1). The second concerns the realisation of what previously planned.

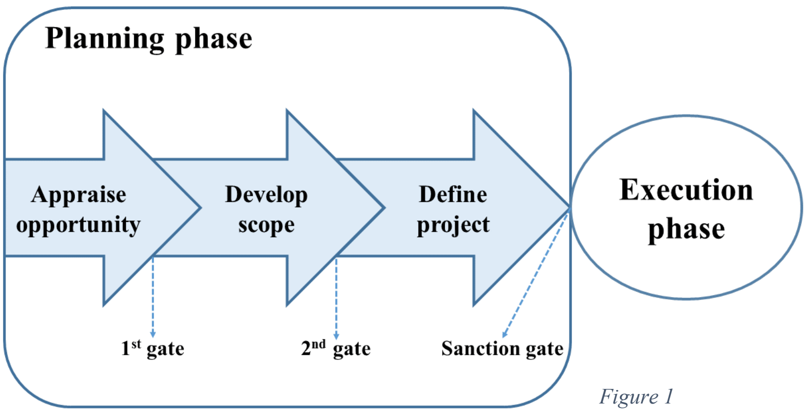

Figure 1

Referring though to common project features, management of cost and time are two project management functions (Turner, 2009) that concern two fundamental aspects of the project itself. Such values unavoidably affect the successful result of the project.

Project management and its success is unavoidably related to decisions affecting an uncertain future. In such situation, forecasting and prediction are fundamental aspects (Anbari, 2003). Uncertainty is also related to project cost and duration, total expenditures and the final date of project execution will be certain only at project conclusion. Therefore it is important to forecast these two outcomes and make estimates that will be the basis to judge the profitability and convenience of the project. Forecasts are important both during planning and execution phase, where they have different purposes.
In planning phase development, estimates are used to assess project viability (Turner, 2009). Once the project execution is authorized, approved estimates become the baseline against which to measure the project performance (Caron, 2009).
During the entire execution phase it is important to ensure that the progress is consistent with the baseline, thus applying the control process shown in figure 2. Performance is measured and cost and time estimates regarding future work are calculated, using the knowledge provided by the work completed.

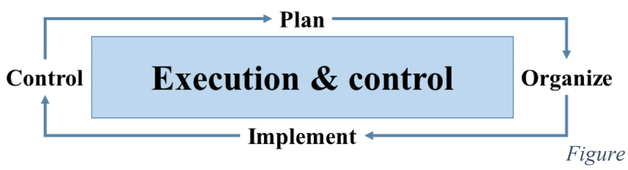

Figure 2

If great differences between the baseline and actual costs and durations are detected, corrective actions are taken or the plan is revised. As the execution phase advances, the accuracy of the estimate increases and the influence of possible corrective actions decreases, as shown in figure 3 (Caron, 2009).

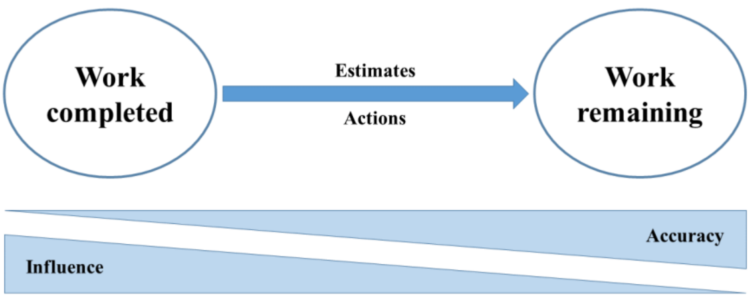

Figure 3

In the context of project cost and duration forecasts, a relevant open issue is represented by systematic errors that are characterized by a tendency to underestimate cost and duration outcomes (Morris, 1990; Flyvbjerg et al., 2002; Merrow, 2011)

Scope

The work presented in this thesis aims at addressing the problem of cost and duration underestimation in project management field. The thesis is developed starting from the problem statement, followed by the explanations assessment and the presentation of corrective methods.
The first purpose is to assess the problem of differences between estimates and actual values of cost and duration, showing that there is a tendency to commit systematic errors towards a general underestimation.
The second purpose is to assess the sources of systematic errors in forecasts, evaluating aspects concerning technical methodologies used to estimate costs and durations, psychological issues and political and organisational influences and pressures.
The third purpose is to present methods to avoid the occurrence of underestimation problems.

Methodology

The entire work is based on literature review and analysis. The state of the art has been analysed to find relevant contribution to the purposes of the thesis.
Studies available in literature have been reviewed to validate the defined problem of project cost and duration underestimation. The principal focus of the work is then a qualitative assessment of the causes of systematic errors in forecasts, such causes are grouped in three categories called explanations, namely technical, psychological and political-organisational. The basis of qualitative assessment are studies conducted in project management and psychological field. The methods proposed as corrective tools are the direct result of the findings of the state of the art review. Finally a general model to post-project review is proposed, in order to improve forecasts. Figure 4 reassumes the methodology followed in the thesis.

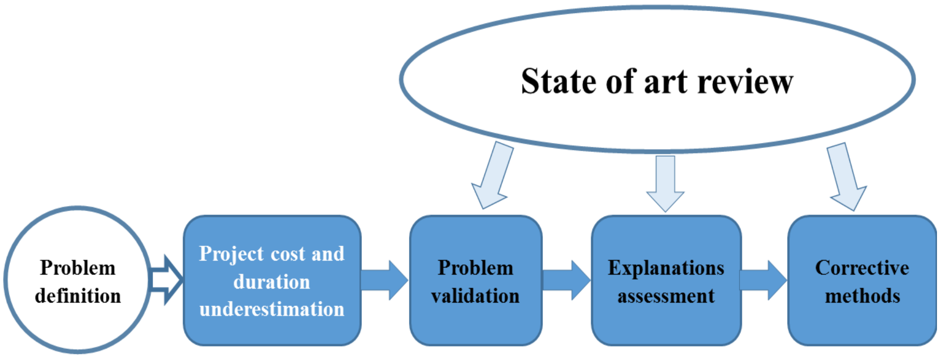

Figure 4

Findings

Studies analysed demonstrated a general tendency to cost and duration underestimation, both in private and public projects (Morris, 1990; Flyvbjerg et al., 2002; Merrow, 2011). In figure 5 the trend of the estimates with respect to the real outcome is shown.

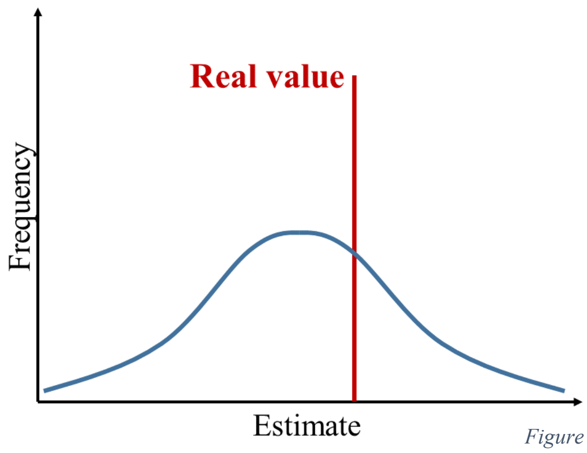

Figure 5

It is possible to notice that estimates are biased, with a tendency to cost and time underestimation. As previously said, the three categories of explanations given for the systematic errors found are: technical explanations, psychological explanations, political-organisational explanations.

Technical explanations concern imperfect techniques, inadequate data, honest

mistakes and lack of experience that lead to inaccurate estimates (Flyvbjerg, 2009). The most critical aspect about forecasting techniques is risk management and project complexity is the most important factor that influences cost and time estimates. Consequently, technical errors strongly depend on imperfections in risk management process and are highly affected by project complexity. The possible consequence of a poor risk management could lead to underrate possible snags, which can finally lead to project cost and duration underestimation.
Technical explanations only partly explain the detected trend of errors in forecasts. Despite the influence of an inadequate risk management, if technical errors were the main source of the problem, a randomly distributed trend of differences between estimates and actual values would be expected.

Psychological explanations concern the errors in the way the mind processes information. Studies showed that people are prone to a general overoptimism when it comes to forecast project cost and duration. This happens both during planning and execution phase (Kahneman and Tversky, 1977; Kahneman and Lovallo, 2003; Kutsch et al. 2011). Such errors are unintentional and can be traced to the following cognitive biases:

- Egocentricity bias
- Outcome attribution
- Confirmation
- Availability
- Representativeness
- Anchoring and adjustment
- Paradox of dispositional optimism
- False consensus and competitor neglect

In literature cognitive biases are accounted to be one of the most important causes for errors in forecasting project outcomes. It is logical to understand how they can lead to cost and duration underestimation. Furthermore it is possible to propose a relation between the biases presented in figure 6: some biases can affect and activate others.

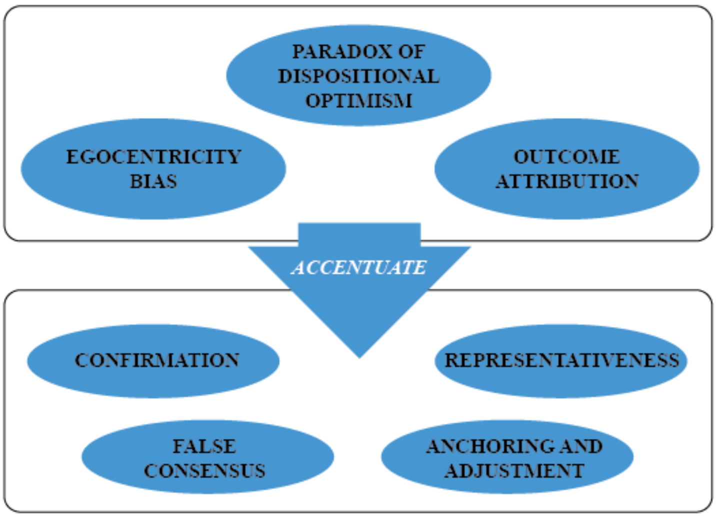

Figure 6

Political and organisational explanations are related to conscious misrepresentation which explains forecasting errors in terms of intentional and strategic misrepresentation. Such misrepresentation can be traced to agency problems and political and organisational pressures (Flyvbjerg, 2009). Pressures to get a particular project, which competes with others, approved are the cause of intentional flaws in forecasting cost and duration outcomes. This interpretation has gained acceptance in the last few years (Flyvbjerg, 2005, 2006, 2009, 2011; Flyvbjerg et al., 2002; Flyvbjerg and COWI, 2004; Pinto, 2013; Wachs, 1989). Political and organisational explanations account well for systematic underestimations of project cost and duration.

In literature there are two principal methods that aim at avoiding or correcting underestimation errors in forecasts.
The first method is the adoption of the 'outside view', also called reference-class forecasting. This approach should help obtaining more objective and reliable forecast by concentrating on comparing the current project to similar past projects (Kahneman and Lovallo, 2003).
The second method is primarily referred to public infrastructure projects, it proposes to correct estimates with up-lifts based on trends of past projects belonging to the same category of the project at hand (Flyvbjerg and COWI, 2004).
Besides the methods proposed in literature, the work conducted in this thesis suggests that practitioners' awareness about possible causes of flawed estimates is a key aspect that may help reaching an overall increased reliability. A post-project review is proposed in order to improve awareness. Such process implies a

meeting after project conclusion between project team members and all people involved in forecasting project cost and duration and approving project viability. The first step is to assess the differences between the estimates and final values (table 1). Then people have to identify the causes of the detected errors. A final documentation will help keeping record of the identified sources of forecasting errors. Table 2 summarizes the salient information about post-project meeting.

Table 1

Parameter	**Definition**	**Formula**
BAC	Budget at completion	
SD	Scheduled duration	
FC	Final cost (actual project cost)	
FD	Final duration (actual project duration)	
FCV	Final Cost Variation	$\frac{FC - BAC}{BAC}$
FDV	Final Duration Variation	$\frac{FD - SD}{SD}$

Table 2

	Post-project meeting
Participants	Project Manager, project team, practitioner involved in forecasting processes (both during planning and execution phase), practitioners involved in project viability approval at planning phase gates
Purpose	Identify FCV and FDV, address differences between cost and time baselines and actual developments, identify sources of errors and possible interactions
Provided documentation	Report FCV, FDV and other significant differences between cost and time estimates and actual values, report technical, psychological and political-organisational factors that influenced estimates

Conclusions

Besides to the proposed method to deal with systematic underestimation, this work could be considered an interesting contribution to the state of the art, as it offers:

- A review of broad studies that document a general trend of cost and duration underestimation in public and industrial projects.

- An overview of the explanations to the above-mentioned problem of systematic errors in forecasts.

- A description of the methods proposed in literature that strive for preventing or correcting biased estimates.

The work conducted in thesis suggests that much more attention should be given to the problem of project cost and duration underestimation and the factors that can influence the latter.

Finally this work could be the basis for future developments in assessing dependencies between different cognitive biases, interviewing project management practitioners about the sources and the relevance of systematic errors in forecasting project cost and duration, and applying the proposed post-project review method in a project-based organisation.

Sommario

Contesto

Gestire un progetto significa avere a che fare con forti componenti di novità e scenari futuri incerti. Ogni progetto è unico e rappresenta un lavoro che ha un inizio, una fine ed è irripetibile nel suo sviluppo. È Tuttavia possibile definire funzioni comuni tra i progetti (Turner, 2009) e un processo generale di gestione che può essere riferito alla maggior parte dei progetti (Caron, 2009).
Concentrandosi sul processo di gestione, è possibile distinguere due fasi principali del ciclo di vita del progetto: fase di pianificazione e fase esecutiva. La prima fase riguarda la definizione dello scopo e la pianificazione del lavoro ed è relativa a tutta la parte del progetto che precede l'autorizzazione ad avviare l'attuazione del lavoro, passaggio definito come 'sanction gate'; questa fase è tipicamente divisa in stadi intermedi (figura 7). La seconda fase riguarda la realizzazione di quanto pianificato in precedenza.

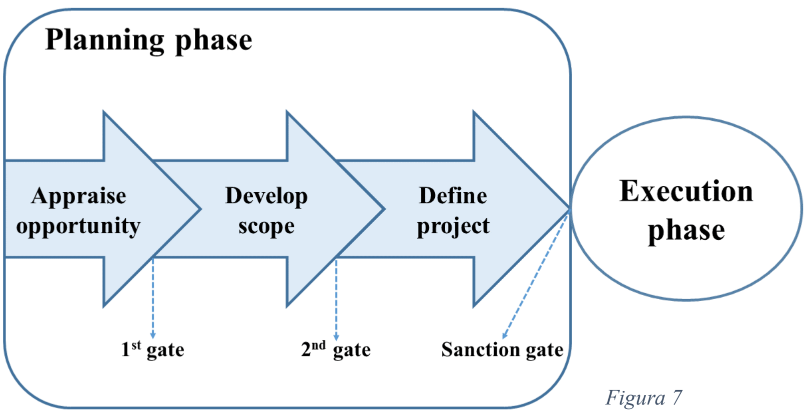

Figura 7

Riferendosi invece alle caratteristiche comuni tra i progetti, la gestione del costo e del tempo sono due funzioni del project management (Turner, 2009) che riguardano due aspetti fondamentale del progetto stesso. Tali valori influiscono inevitabilmente sul successo del progetto.

La gestione del progetto e la sua riuscita sono inevitabilmente correlate a decisioni che riguardano un futuro incerto. In tale situazione, le previsioni giocano un ruolo fondamentale (Anbari, 2003). L'incertezza riguarda anche il costo del progetto e la sua durata: le spese totali e la data di completamento del progetto saranno dei valori certi soltanto al termine dell'esecuzione del progetto stesso. Pertanto è importante prevedere questi due risultati e fare stime che saranno la base per poter giudicare la redditività e la convenienza del progetto. Le previsioni sono importanti sia in fase di pianificazione che durante l'esecuzione, avendo rispettivamente scopi diversi.
In fase di pianificazione, le stime sono utilizzate per valutare la fattibilità del progetto (Turner, 2009). Una volta che l'esecuzione del progetto viene autorizzata, le stime approvate diventano la baseline rispetto a cui misurare le prestazioni di progetto (Caron, 2009).
Durante l'intera fase di esecuzione, è importante garantire che l'avanzamento sia coerente e in linea rispetto alla baseline, applicando quindi il processo di controllo illustrato in figura 8. La performance viene misurata e vengono calcolate stime di costi e tempi riguardo i futuri sviluppi dei lavori, utilizzando le conoscenze rese disponibili dal lavoro completato.

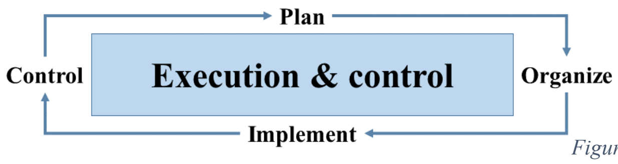

Figura 8

Se vengono rilevate grandi differenze tra la baseline e i costi e le durate effettivi, vi è la necessità di applicare misure correttive o di rivalutare i piani. Con l'avanzare della fase di esecuzione, la precisione delle stime aumenta e l'influenza di possibili azioni correttive diminuisce, come mostrato in figura 9 (Caron, 2009).

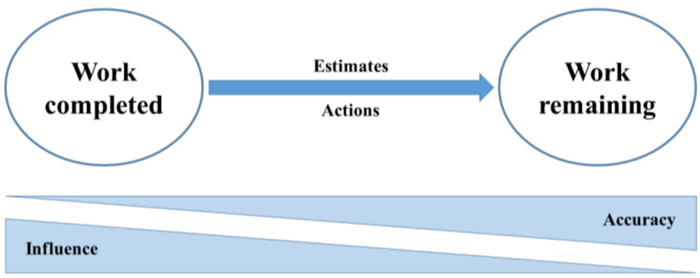

Figura 9

Nel contesto delle previsioni di costi e durate dei progetti, un'importante questione aperta è rappresentata dagli errori sistematici, caratterizzati da una tendenza verso la sottovalutazione dei valori di costo e durata (Morris, 1990; Flyvbjerg et al, 2002; Merrow, 2011)

Scopo

Il lavoro presentato in questa tesi si propone di affrontare il problema delle sottostime di costi e durate nel campo della gestione del progetto. La tesi si sviluppa a partire dalla definizione del problema, seguita dalla valutazione delle spiegazioni e dalla presentazione di metodi correttivi.
Il primo scopo è quello di valutare il problema delle differenze tra le stime e i valori reali di costo e durata, dimostrando che c'è una tendenza a commettere errori sistematici caratterizzati da una generale sottovalutazione.
Il secondo scopo è quello di valutare le fonti di errori sistematici nelle previsioni, valutando gli aspetti riguardanti le tecniche utilizzate per la stima di costi e tempi, le questioni psicologiche e le influenze politiche e organizzative.
Il terzo scopo è quello di presentare metodi per evitare l'insorgere di problemi di sottostima.

Metodologia

L'intero lavoro si basa sulla revisione l'analisi dello stato dell'arte, al fine di trovare contributi rilevanti riguardo gli argomenti trattati.
Gli studi disponibili in letteratura sono stati analizzati per validare la definizione del problema di sottostima di costi e durate dei progetti. L'obiettivo principale del lavoro è quindi una valutazione qualitativa delle cause degli errori sistematici nelle previsioni, tali cause sono raggruppati nelle seguenti categorie (denominate spiegazioni): spiegazioni tecniche, spiegazioni psicologiche e spiegazioni politico-organizzative. La base di valutazione qualitativa sono studi condotti nell'ambito del project management e nell'ambito psicologico. I metodi proposti come strumenti correttivi sono il risultato diretto delle risultanze della revisione dello stato dell'arte. Infine viene proposto un modello generale di post-project review, al fine di migliorare le previsioni. La figura 10 riassume la metodologia seguita nella tesi.

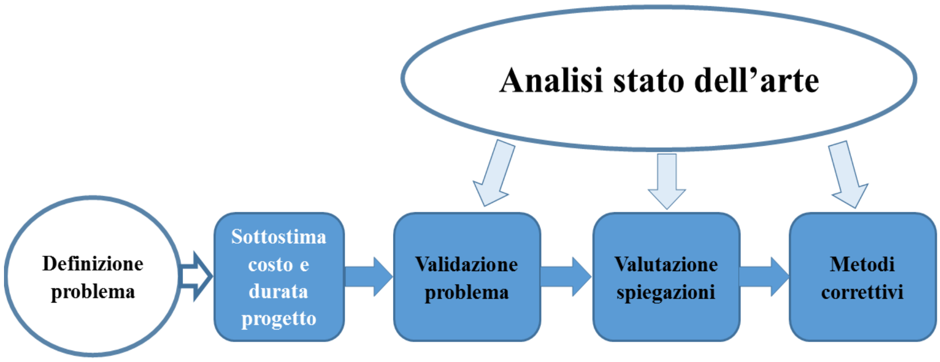

Figura 10

Risultati

I risultati di questo lavoro di tesi sono puramente qualitativi. Gli studi analizzati hanno dimostrato una tendenza generale a sottovalutare i costi e le durate, nei progetti pubblici e privati (Morris, 1990;. Flyvbjerg et al, 2002; Merrow, 2011). Nella figura 11 viene mostrato l'andamento delle stime rispetto al risultato reale.

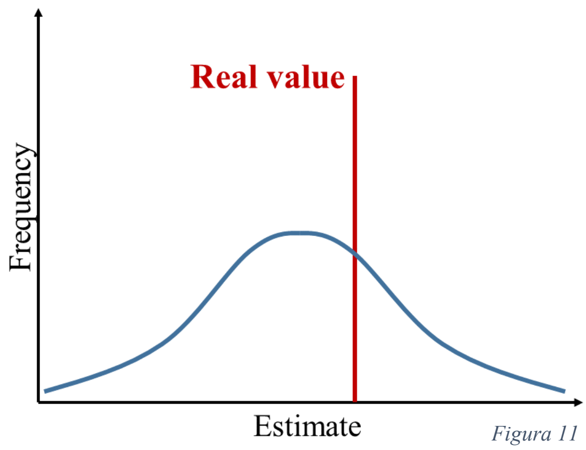

Figura 11

E 'possibile notare che le stime sono affette da errori sistematici, con una tendenza alla sottovalutazione di costi e tempi. Come detto in precedenza, le tre categorie di spiegazioni fornite per gli errori sistematici trovati sono: spiegazioni tecniche, spiegazioni psicologiche, spiegazioni politico-organizzative.

Le spiegazioni tecniche riguardano tecniche imperfette, dati inadeguati, errori involontari e mancanza di esperienza che portano a stime imprecise (Flyvbjerg, 2009). L'aspetto più critico riguardo le tecniche di previsione è la gestione dei rischi, mentre la complessità del progetto è il fattore più importante che influenza le stime dei costi e di tempo. Di conseguenza, gli errori tecnici dipendono fortemente da imperfezioni nel processo di gestione dei rischi e sono altamente influenzati dalla complessità del progetto. La possibile conseguenza di una cattiva gestione dei rischi potrebbe portare a sottovalutare eventuali complicazioni, portando di conseguenza a sottostimare i costi e la durata del progetto.
Le spiegazioni tecniche giustificano solo in parte l'andamento rilevato degli errori nelle previsioni. Nonostante l'influenza di una gestione inadeguata dei rischi, se gli errori tecnici fossero la fonte principale del problema, ci si aspetterebbe una distribuzione casuale delle differenze tra stime e valori effettivi.

Le spiegazioni psicologiche riguardano errori che si verificano nell'elaborazione mentale delle informazioni. Gli studi hanno dimostrato che le persone sono inclini a un eccessivo ottimismo generale nel prevedere costi e tempi di durata dei progetti. Questo fenomeno avviene sia in fase di progettazione che in fase di esecuzione (Kahneman e Tversky, 1977; Kahneman e Lovallo, 2003;. Kutsch et al 2011). Tali errori sono involontari e possono essere ricondotte ai seguenti bias cognitivi (viene indicata la definizione in inglese con rispettiva traduzione):

- Egocentricity bias *(bias di egocentrismo)*
- Outcome attribution *(attribuzione dei risultati)*
- Confirmation *(conferma)*
- Availability *(disponibilità)*
- Representativeness *(rappresentatività)*
- Anchoring and adjustment *(ancoraggio e regolazione)*
- Paradox of dispositional optimism *(paradosso di ottimismo disposizionale)*
- False consensus and competitor neglect *(falso consenso e scarsa considerazione della concorrenza)*

Dall'analisi dello stato dell'arte, i bias cognitivi sono considerati una delle cause più importanti degli errori di previsione. È logico capire come questi possano portare alla sottostima di costi e tempi. Inoltre è possibile proporre una relazione tra bias presentata in figura 12: alcuni bias possono influenzare e attivarne altri.

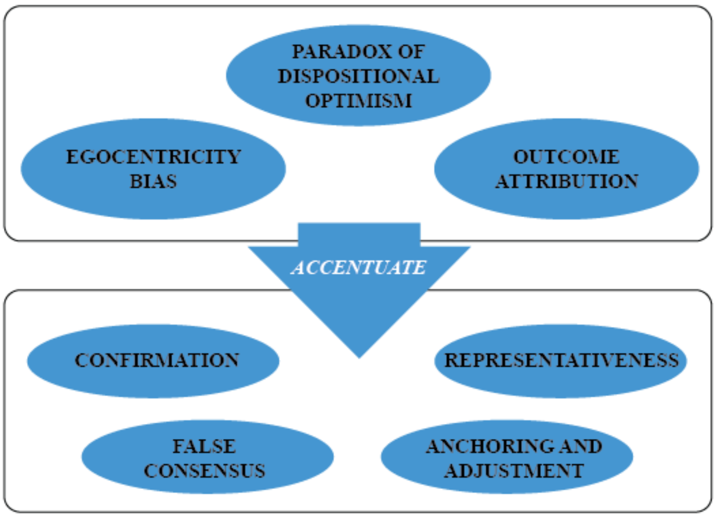

Figura 12

Le spiegazioni politiche e aziendali riguardano rappresentazioni consapevolmente errate riguardo i costi e le durate dei progetti. Tali false dichiarazioni possono essere ricondotte a pressioni politiche e aziendali (Flyvbjerg, 2009). L'ambizione e la volontà di vedere approvato un particolare progetto, che si trova in competizione con altri, sono la causa di errori intenzionali nella stima di costi e tempi di durata. Questa interpretazione ha guadagnato notevole riconoscimento negli ultimi anni (Flyvbjerg, 2005, 2006, 2009, 2011; Flyvbjerg et al, 2002;. Flyvbjerg e COWI, 2004; Pinto, 2013; Wachs, 1989). Le spiegazioni politiche e aziendali rappresentano una valida motivazione per sottostime sistematiche di costi e durate dei progetti.

Dall'analisi dello stato dell'arte emergono due metodi principali che mirano a evitare o correggere errori di sottostima nelle previsioni.
Il primo metodo è l'adozione della 'outside view', chiamata anche 'reference class forecasting'. Questo approccio dovrebbe aiutare a ottenere previsioni più oggettive e affidabili, concentrandosi sul confronto tra l'attuale progetto e progetti simili già conclusi (Kahneman and Lovallo, 2003).
Il secondo metodo si riferisce principalmente a progetti pubblici di infrastrutture e si propone di correggere le stime con una revisione al rialzo delle stime, in base agli andamenti dei progetti passati appartenenti alla stessa categoria del progetto considerato (Flyvbjerg and COWI, 2004).
Oltre ai metodi proposti in letteratura, il lavoro svolto in questa tesi suggerisce che la consapevolezza sulle possibili cause di errori di previsione è un aspetto fondamentale che può aiutare a raggiungere una maggiore affidabilità

complessiva. Viene quindi proposto un modello di post-project review, al fine di migliorare la consapevolezza. Tale processo implica un meeting successivo alla conclusione del progetto, a cui partecipano i membri del project team e tutte le persone coinvolte nella previsione di costi e tempi e nell'approvazione della fattibilità del progetto. Il primo passo è quello di valutare le differenze tra le stime e valori finali (tabella 3). Poi le persone presenti al meeting dovranno identificare le cause degli errori rilevati. Una documentazione finale aiuterà al fine di conservare e divulgare i dati delle cause identificate. La tabella 4 riassume le informazioni salienti riguardanti il meeting.

Tabella 3

Parameter	**Definition**	**Formula**
BAC	Budget at completion	
SD	Scheduled duration	
FC	Final cost (actual project cost)	
FD	Final duration (actual project duration)	
FCV	Final Cost Variation	$\frac{FC - BAC}{BAC}$
FDV	Final Duration Variation	$\frac{FD - SD}{SD}$

Tabella 4

	Post-project meeting
Partecipanti	Project Manager, project team, persone coinvolte nelle previsioni (sia nella fase di pianificazione che in quella esecutiva), persone coinvolte nell'approvazione del progetto
Scopo	Identificare FCV e FDV, valutare differenze tra baseline ed effettivi costi e durate, identificare cause degli errori e possibili interazioni
Documentazione	Report su FCV, FDV differenze significative, report su fattori tecnici, psicologici e politico-aziendali che hanno influenzato le previsioni

Conclusioni

Oltre al metodo proposto per affrontare la sottostima sistematica di costi e durate, questo lavoro può essere considerato un interessante contributo allo stato dell'arte, in quanto offre:

- Una rassegna di studi che documentano una tendenza generale alla sottostima di costi e durate in progetti pubblici e industriali.

- Un’ampia analisi delle spiegazioni al problema di errori sistematici nelle previsioni.

- Una descrizione dei metodi che puntano alla prevenzione o correzione di stime distorte.

Il lavoro condotto nella tesi suggerisce che molta più attenzione dovrebbe essere data al problema di sottostima di costi e durate dei progetti e ai fattori che possono portare all’insorgere del problema stesso.
Infine questo lavoro potrebbe essere la base per futuri sviluppi nella valutazione di dipendenze tra le diverse distorsioni cognitive, nella rilevazione delle cause di errori sistematici nella previsione di costi e durate, nell’applicazione pratica del metodo proposto di post-project review.

Introduction

Project management is an extremely challenging field, both for academic studies and industrial developments. Novelty and uniqueness are the principal characteristics that feature projects, thus making their management a gauntlet where coordination of skills, labour and people must always stay at high levels of performance, in order to reach fixed objectives that can guarantee the desired benefits and profit.
In a such mutable scenario, where the bar has been continuously raised in the course of time, the right vision of future developments is key to success. Therefore forecasts play a fundamental role in every project, being a powerful and important tool that permits to steer implementations towards the successful direction.
Hence it is possible to understand how forecasts are a relevant matter of concern in several researches. Forecasting techniques and methods are constantly refined thanks to studies and methodology proposals that strive for a continuous improvement.

In this thesis, forecasts are the broad addressed subject and the starting point from which attention is then put on specific issues. In the first chapter cost and duration forecasts will be introduced, focusing on the aspects relevant to the topics that will follow. Then the work will concern three subsequent issues, related to the three principal purposes of the thesis:

- First, the problem of systematic errors in forecasting project cost and duration will be addressed. A general trend of cost and duration underestimation will arise, under the validation of important and wide studies in literature.

- Second, the explanations to the given systematic errors will be presented. Such explanations are divided into three categories: technical, psychological and political-organisational.

- Third, methods to avoid and correct systematic errors will be presented. Besides methods provided by literature, a process to help improve forecasts will be proposed.

These three issues will be addressed from chapter 2 to chapter 6. Chapter 2 concerns systematic errors, chapters 3, 4 and 5 the explanations and chapter 6 the corrective methods. In the seventh and final chapter, conclusions will be drawn.

Chapter 1

Forecasting project cost and duration

1.1 The importance of cost and time estimates

Project management is primarily related to decisions affecting the future. It is extremely important to make and take decisions based on reliable data and on a highest possible degree of awareness, in order to be as sure as possible to make the right choices that can lead to beneficial results.
Therefore, forecasting and prediction are fundamental aspects of project management (Anbari, 2003). Understanding the possible future scenarios for the project development is the key to successful decisions, consequently estimates about the project outcomes are needed to evaluate the right actions to take.

The management of cost and time are two project management functions (Turner, 2009) and cost and time are undoubtedly two relevant aspects of the project. Cost and duration are values that unavoidably influence the project success. Hence, to make right decisions and positively affect the future project development in order to reach successful outcomes, cost and time estimates play a fundamental role during the entire project life-cycle.
Cost and duration estimates are the output of the forecasting process, which is consequently of high relevance to the whole project management. The forecasting process concerns all the procedures done to calculate the estimated values of the project outcomes; such process is developed starting from the concept phase, until the last stages of the execution phase of the project.
Therefore it is important to understand the factors that can influence forecasts and cost and time estimates: starting by these factors, a cascade of conditioning can pass through the estimates and finally affect the key decisions. In the forthcoming chapters some aspects about the forecasting process will be addressed, like uncertainty, risk and the use of knowledge, which are relevant aspects concerning specific topics discussed in this thesis; however the purpose is not to go in deep

on the methodologies and techniques used in the forecasting process, but to focus on how it can be influenced.

1.1.1 Cost estimates

According to the Project Management Institute (PMI, 2000), “cost estimating involves an approximation (estimate) of the cost of the resources needed to complete project activities”. As previously said, it is not in the interest of this study to address the techniques used in cost estimating, instead it is interesting to briefly explain the type of resources that can be the subject of cost estimating, thus introducing the components of cost; these mainly depend on the type of project, however costs can be categorized and divided between the following components (Turner, 2009):

- Labour: the cost of people employed by the parent organisation, involved in project tasks related to the entire project life-cycle.
- Materials: the cost of materials consumed in executing the project.
- Plant and equipment: the cost of the materials used in implementing the project execution, but which are not consumed.
- Subcontract: the cost of labours and materials provided by subcontractors.
- Management overheads and administration: the cost of people and materials to manage the project.
- Finance: the cost of obtaining loan capital.
- Fees and taxation: the cost of insurance and taxes.
- Inflation: the cost of the variation of currency value during the whole project duration.
- Contingency: the money set aside for covering cost items which aren’t exactly known.

Costs can also be classified according to their use. It is possible to distinguish between costs billed directly to the project (direct costs) and costs that aren’t directly accountable to the project (indirect costs); a further distinction is between costs traced to the use of the organisation's internal resources (internal costs) and resources external to the organisation (external costs) (Caron, 2009). Costs are also made up of two different types of elements: time-dependent elements (the project team members' salaries for instance) and work dependent elements (labour for instance)

1.1.2 Time estimates

Time estimates are the results of forecasting project activities durations, thus being "the process of taking information on project scope and resources and then developing durations for input to schedules" (PMI, 2000). Estimating project activities durations is part of the process required to ensure timely completion of the project (PMI, 2000), which is fundamental to derive revenues at times that give satisfactory return on investment (Turner, 2009). Such process is characterized by subsequent steps that have to lead to the project time schedule: a series of dates against the work of the project (Turner, 2009).
According to the Project Management Institute (PMI, 2000), the following steps can be generally identified in the time management process:

- Activity definition: identify and document the specific activities that must be performed according to the project scope defined

- Activity sequencing: identify and document interactivity logical relationships, thus defining the temporal dependencies of the project activities

- Activity duration estimating: establish the project activities durations

- Schedule development: determine start and finish dates for project activities

- Schedule control: control changes to the project schedule

1.1.3 Relations between cost and duration

Cost and duration are two aspects of project activities unavoidably interdependent. As previously stated, there are cost elements that are time-dependent, this means that the cost of the time-dependent element depends on the duration of the element (could be a subcontract, for instance). Focusing instead on work-dependent elements previously cited, due to interferences between people working, when trying to shorten too much an activity duration the possible

consequence could be a higher cost of the considered activity. To explain it with an example, if 20 people can complete an activity in 10 days, it is almost impossible that 100 people manage to do it in 2 days (Turner, 2009).
When putting together work-dependent and time-dependent costs, it is possible to notice that there is an optimal time window for the activity duration, as showed in figure 1.1. Generally direct costs are work-dependent costs (labour cost is an example) and indirect costs are time-dependent (project team salaries), consequently an optimal compromise should be found between them.

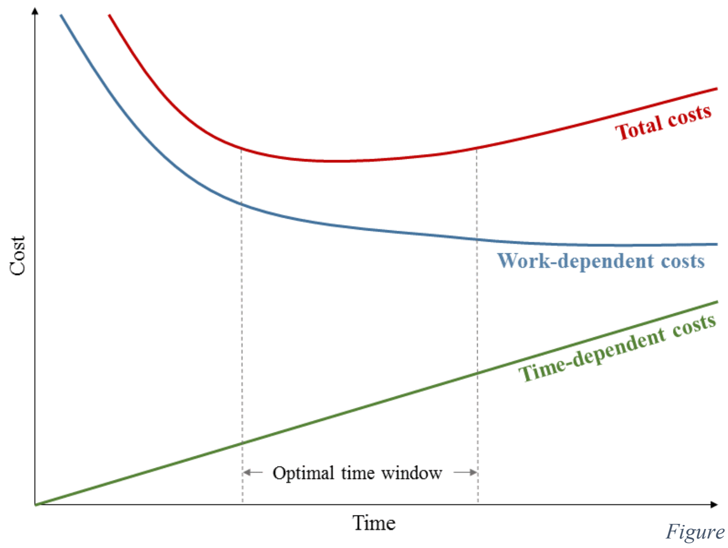

Figure 1.1

Another relevant aspect regarding cost and time relationship is the management of cost consumption against the planned implementation profile and, consequently, the financing rate. As shown in figure 1.2, a zealous execution can cause a cash consumption rate too high with respect to the plans (Turner, 2009). Therefore project implementation needs to proceed according to the permission of constant cash availability.

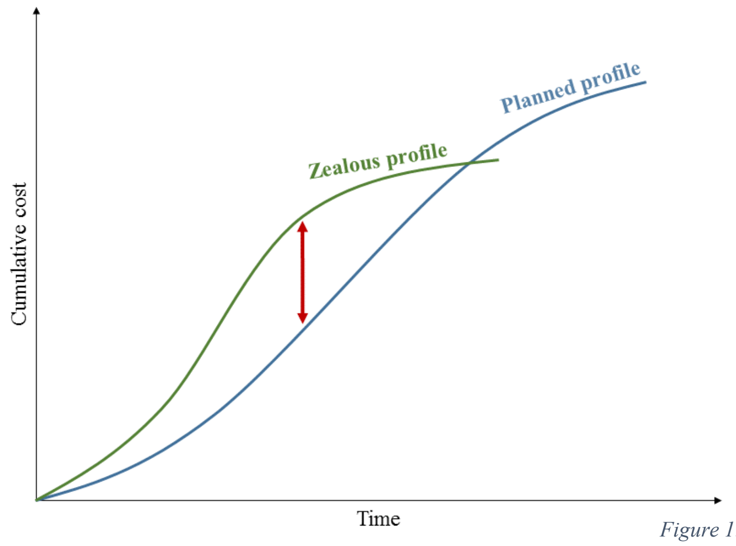

Figure 1.2

The last important issue about cost and time interdependency is that maximum returns may not correspond to minimum costs, as shown in figure 1.3 (Turner, 2009). The facility provided at project completion can have a value that decays with time, so the ultimate optimization needs to be done with the aim of obtaining the maximum benefit and profit.

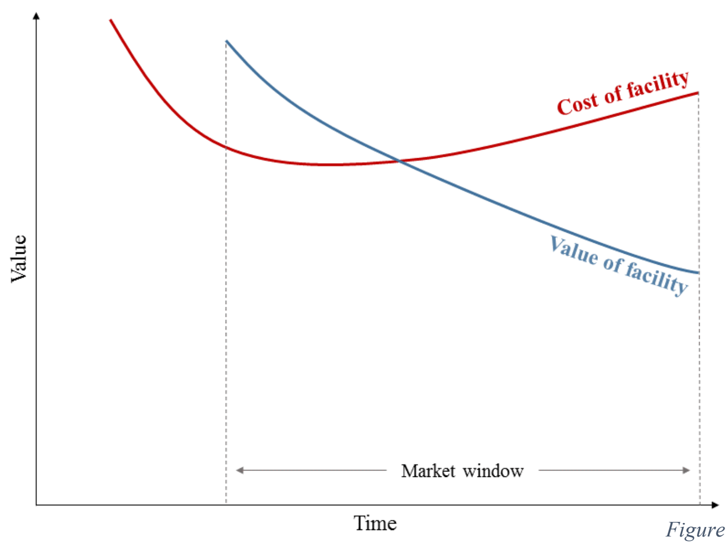

Figure 1.3

1.2 Forecasting during planning phase

To better explain the issues discussed in this thesis, it is important to clarify the difference between two main phases of the project life-cycle. With reference to the planning phase, the entire part of the project prior to authorization is indicated (figure 1.4). This phase is related to the definition of the project goals and the planning of what will be further executed. With reference to execution phase, the part of the project that starts after authorization and ends with the delivery of the facility is indicated. This phase is related to the realisation of what was previously planned.

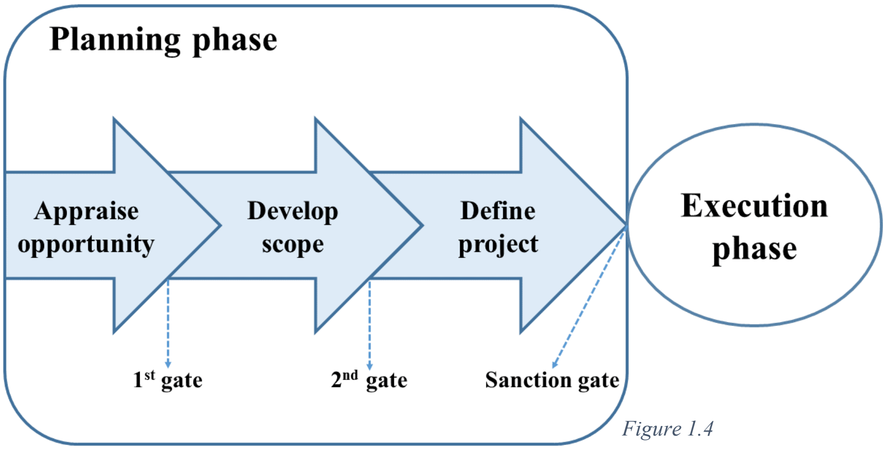

Figure 1.4

Figure 1.4 also shows that the planning phase (that can be called with different definitions) is typically divided into partial stages.

1.2.1 Planning phase development

As previously anticipated, the planning phase is divided into phases or stages. Between each phase there is a pause for an assessment and decision about whether proceed. These decision points are generally called gates. Every stage of planning phase ends with a gate. The number of stages is not of high importance; however they could be generally between three to more than thirty (Merrow, 2011).
It is important to assess the viability of the project at every gate, this assessment is based on economic and business examinations. If the project is considered worth undertaking, it passes to the next stage. Obviously here estimates play a fundamental role: cost estimates are the basis of the gate evaluations to start understanding if a project is economically worthwhile.

Logically, as the planning phase progresses through the different stages, the scenario becomes increasingly clear. The last and most important gate is defined as sanction gate (it can be called with different other names like 'authorization' or 'Final Investment Decision'). This gate triggers the full commitment of funds (Merrow, 2011) and enshrines the beginning of the execution phase

1.2.2 Purpose of forecasting during planning phase

Cost and time estimates serve for several reasons. Typically during planning phase they are used for the followings (Turner, 2009):

- Assess viability: as previously stated, during planning phase it is important to understand if the efforts to take the project to the next stage is worthwhile. There's the need to compare cost estimates to the possibilities of return and evaluate if the organisation is able to undertake the project, considering the possible cost and duration.

- Obtain funding and prepare tender: the project needs to be financed, in order to be implemented. Cost and time estimate represent the basis for funding approval and for the development of a financial plan. If the organisation is preparing a tender, cost and time estimates need to be prepared and presented. The purpose of obtaining funding and preparing tender, with respect to cost and time estimates, is crucial to the issues addressed in the next chapters.

- Manage resources: human resources and also materials need to be allocated for the project activities implementation. Allocation is planned in advance against the estimates.

- Estimates as a baseline: cost and time estimates approved at the sanction gate represent a measure against which to control the project execution. Time estimates, once approved, become the schedule of the activities. Cost estimates become the cost baseline, representing the planned cash-flow development.

1.2.3 Planning phase estimates development

As the project scope becomes increasingly clear going through the various stages of planning phase, the same trend needs to be followed by cost and time estimates. At every gate, if the project proceeds, estimates are approved. The

range of accuracy regarding these estimates is increasingly reduced.
Therefore first estimates are characterized by scarce accuracy and are the result of elementary forecasting processes. The data available as input to forecasts are few and not detailed. Consequently the level of effort put to calculate estimates is low (Turner, 2009).
As the planning phase proceeds, raw estimates become more accurate, input data improve and the effort put into forecasting process increases, as shown in figure 1.5.

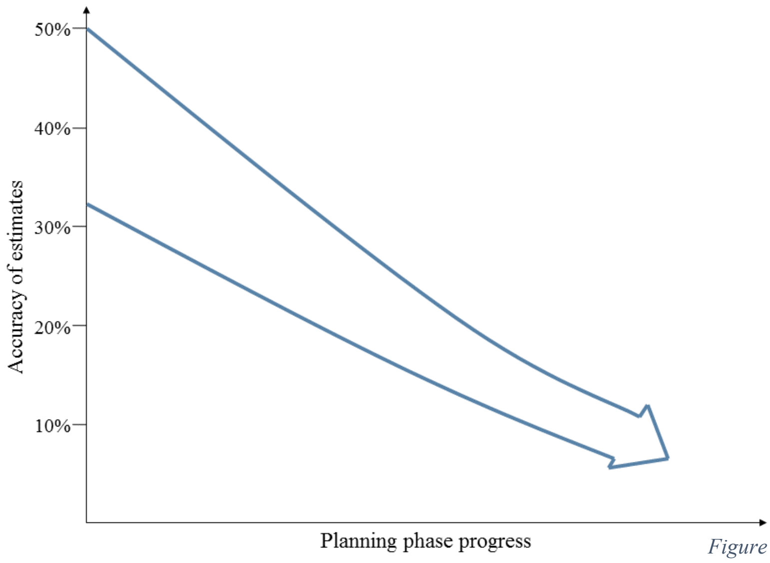

Figure 1.5

Concerning the efforts put to calculate estimates, which is evaluated as percentage of the project total cost, it is important to remember that such efforts are rewarded by possible savings during execution phase. This means that forecasts, which represent efforts that obviously cost money, don't have to cost more than the value of the estimates (Turner, 2009).

1.3 Forecasting during execution phase

It has been already stated that execution phase refers to the part of the project life-cycle where work to deliver the objectives is done. Once the project has passed the sanction gate, work can begin. During this phase, the development needs to proceed according to the plans; in particular, activities implementation

and expenditure have to follow the schedule and the cost baseline approved at the sanction gate.
Measuring the progress is then of high importance, in order to ensure that implementation is following the plan.

1.3.1 Execution phase development

Project execution phase is strictly related to the nature of the project, hence it is difficult to find a general process common to every kind of project. However a typical trend of the execution phase can be found, especially in large and complex projects. The implementation is characterized by an initial phase when the progress rate increases as the execution proceeds and a final phase when it decreases; in the central phase the progress is constant, as shown in figure 1.6 (Caron, 2009).

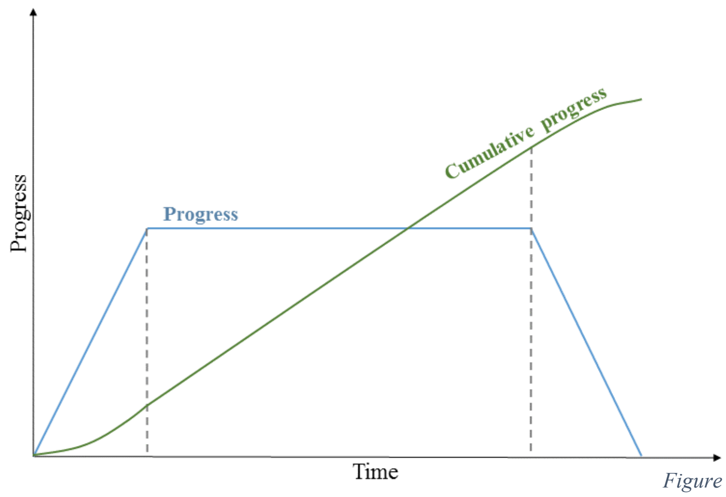

Figure 1.6

The result of the cumulative progress is a trend called ‘S-Curve’. This trend represents the planned development of the execution phase. Generally the measures graphed are cost and time, thus referring to the cost of the work implemented and the related duration.

1.3.2 Purpose of forecasting during execution phase

Once budget and time baseline are defined, cost and duration objective are fixed. To reach such objectives, it is important to make sure that implementation is proceeding according to the plan, thus applying the control process shown in figure 1.7.

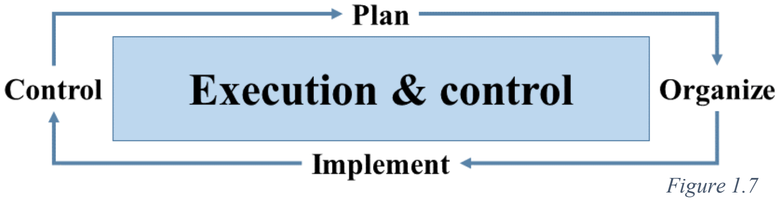

Figure 1.7

Starting from the baseline, the work is organised and implemented and it is extremely important to record the progress and compare it with the planning estimates. Hence a continuous forecasting process follows the execution phase, updating the estimate values. If the differences are relevant, it will be necessary to take action and revise the plan.
Particular aspects about the purpose of controlling the performance are:

- Update the estimate to completion: For performance trends significantly different from the plans, cost and duration estimates are revised.

- Control resource allocation: it is possible (and it often happens) that execution phase doesn't go as expected and planned. For the activities that present such situation, a resource reallocation is needed.

- Manage cash flows: a high progress rate could seem always a positive issue. However, an excessively zealous implementation can lead to the situation explained in 1.1.3. Therefore high performance variances, both positive and negative, have to be avoided.

1.3.3 Execution phase estimates development

The control cycle previously explained follows the entire project execution phase. Variances are recorded and, if needed, estimates to completion are revised or action are taken to change the performance trend and manage to realise the cost and duration objectives stated at the sanction gate. It is important to underline the effort made to calculate performance variances and estimates is extremely higher with respect to the planning phase (Turner, 2009).

At a generic time now, performance about work completed are recorded and

estimates about work remaining are calculated. Earned Value Management (EVM) is a tool that permits to integrate scope, cost and time; it provides indications about expected future results based on performance related to work completed (Anbari, 2003).
Table 1.1 summarizes the typical parameters of Earned Value Management and Earned Schedule (ES), a further tool that focuses on duration estimates (Lipke, 2003). Figures 1.8 and 1.9 show the representation of the salient parameters, respectively for Earned Value and Earned Schedule, in case of a trend with performance lower than planned, both for cost and schedule.

Table 1.1

Parameter	**Definition**	**Description**	**Formula**
BAC	Budget at completion	Budget approved at sanction gate	
BCWS	Budget cost work scheduled	Approved budget for work scheduled to be completed	
BCWP	Budget cost work performed	Approved budget for work actually completed	
ACWP	Actual cost work performed	Cost actually incurred for work completed	
BCWR	Budget cost work remaining	Approved budget for work remaining	BAC-BCWP
ETC	Estimate to complete	Estimated cost for work remaining	BCWR/CPI
EAC	Estimate at completion	Estimated final cost	ACWP+ETC
SV($)	Schedule variance (EVM)	Difference between budgeted work and work actually performed	BCWP-BCWS
CV	Cost variance	Difference between budgeted cash flow and actual cost for work performed	BCWP-ACWP
SPI($)	Schedule performance index (EVM)	Ratio of approved budget for work performed to approved budget for work planned	BCWP/BCWS
CPI	Cost performance index	Ratio of approved budget for work performed to actual expenditure	BCWP/ACWP

ES	Earned Schedule	Time at which actual cumulative progress would be reached following the plan	
SV(t)	Schedule variance (ES)	Difference between work performed and Earned Schedule	ES-AT
SPI(t)	Schedule performance index (ES)	Ratio between Earned Schedule and time now (Actual Time)	ES/AT

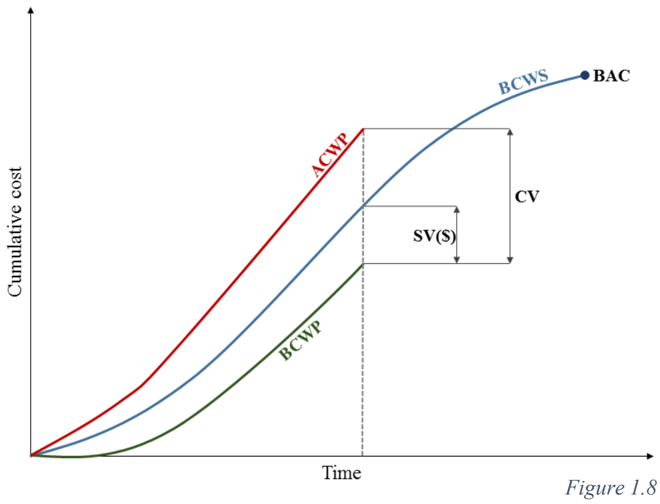

Figure 1.8

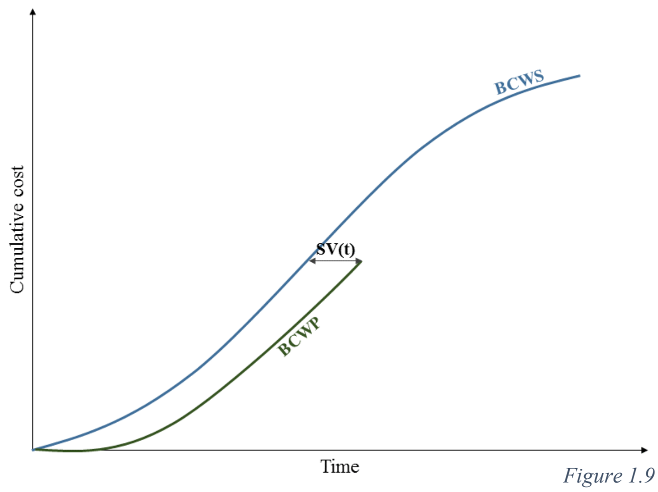

Figure 1.9

The two main aspects of managing the execution phase are the estimates accuracy and the influence of possible corrective actions. Obviously, when evaluated at a time now near to the execution phase beginning, estimates are at an accuracy level similar to the baseline approved at sanction gate and corrective action can have a high impact on the project outcomes. On the contrary, coming closer to the end, estimates represent almost certain values and corrective actions are irrelevant (Caron, 2009). Figure 1.10 shows this trend.

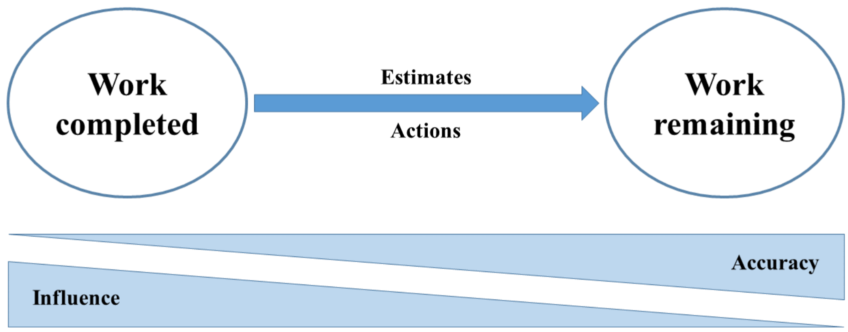

Figure 1.10

Chapter 2

Systematic errors in forecasting

2.1 Differences between estimates and final values

In the previous chapter forecasting methods, their purpose and their importance were addressed. It is clear how the key aspect about forecasting methods and estimates is reliability. Reliable estimates give a true and realistic vision of future development, leading to take right choices during the entire project development. Hence reliable estimates and correct forecasting processes are fundamental to obtain successful results.

Estimates reliability could be a wide problem, concerning different issues. However forecasts, by definition, give values about future outcomes and this is undoubtedly the case of costs and duration. Therefore it is possible to focus on accuracy, in order to assess estimates reliability. This means that to evaluate estimates, these are compared to the final results of the predicted outcome after project completion. Consequently differences are addressed. An Estimate is considered 'ex-post' accurate if the final value after project completion falls inside the accuracy range established when estimate was calculated.
The most relevant difference is the one between final cost and duration outcomes and estimates approved at sanction gate, as the latter also represent the baselines for expenditures and schedule, as stated in the previous chapter.

The first purpose of this thesis is to address the differences between cost and duration estimates and corresponding final values. The data available from literature will be evaluated in this chapter, in order to understand which are the historical trends. Obviously the interest is to understand whether a systematic pattern is present, as the trivial expectation is to have randomly distributed differences.

2.1.1 Accessibility to historical data

To evaluate differences between estimates and final values, of course it is necessary to obtain access to information concerning projects, their management and their development. As suggested by Merrow, it is not easy to find studies that make available these kind of information (Merrow, 2011):

“Research on capital projects, especially in the private sector, is sorely hampered by the researcher’s lack of access to data and the people who created those data”

It is understandable how difficult could be the work of data collection in private sector. Organisations usually keep these kinds of information secret and hardly divulge them. Furthermore it is logical to think that private organisations avoid disclosing information about unsuccessful projects, thus preventing adverse publicity on the organisation itself (Merrow, 2011).

Researches on public projects may present more accessibility to data. However public projects are usually managed by private organisations, therefore the same difficulties previously described about accessing to practitioners shows. In addition, in public sector, officially declared budget and schedule may be lower than real cost and time objectives, due to an attitude to publicize low budgets in order to gain approval in the political system (Flyvbjerg et al., 2009). This issue balances the apparently higher accessibility to information, resulting in an overall situation similar to private projects.

2.1.2 Historical data available

Despite the difficult research scenario described, there are studies that succeeded in gathering and assessing information and data about a significant number of projects, both in private and public sector.

Public sector, which presents a wider range of disclosed information, is subject of different researches, many of them are conducted on projects related to a specific country, focusing on the differences between approved estimates and final values and trying to assess the causes. There are also studies which try to give a broad perspective about cost and duration differences between estimated and final values in public project management. Such studies analyse data regarding medium to large public projects all over the world, primarily in infrastructure.

Private sector, as said, is characterized by low data accessibility. Fortunately

Independent Project Analysis managed in collecting information concerning more than 700 industrial projects in the course of a year. This was possible thanks to private organisations which benchmarked their projects with the said corporation, permitting the access to writing record of projects and the people who developed and executed the projects themselves, resulting in a study finally focused on more than 300 industrial megaprojects (Merrow, 2011).

2.2 Cost and time overruns in public projects

The data presented in this section are referred to two large studies regarding public projects, as previously anticipated. Obviously such studies aren't the only researches on differences between estimates and real project outcomes, it is interesting to present them as they are well detailed and focused on issue strictly related to this thesis. These two studies present a quite clear scenario of systematic underestimation for cost and duration project outcomes. Analysing hundreds of public projects, these studies arrive to the conclusion that budgets approved at sanction gate and schedules aren't usually met by the real values obtained at project conclusion.

2.2.1 The Morris study

Interesting information are provided by one of the first researches that focuses on cost and time overruns in project management (Morris, 1990). Though such research presents data related to year 1989, it is still actual and relevant. According to this study, which analyses 290 medium and large public projects conducted in India, delays and cost overruns have become a regular feature of public sector projects starting from the early sixties. In addition, the author complains about the difficulty to collect information. Tables 2.1 and 2.2 sum up the salient information about the projects subject of this research. Data of total costs aren't reported, as their interpretation, due to the period and location of such projects, are complicated and not immediate, besides being not so relevant as overrun data.
Table 2.1 provide general information about cost and time overruns in the projects analysed. Table 2.2 provides specific information about 133 projects that suffered from cost and time overruns and had available detailed data; also information about the nature of the projects are presented.

Table 2.1

Number of projects analysed	290
Number of projects having cost overrun	186
Range of cost overrun	0-961 %
Number of projects having time overrun	162
Range of time overrun	0-204 %

Table 2.2

Sector	**No of projects**	**Time overrun [%]**	**Cost overrun [%]**
Railway	23	69.85	164.21
Steel	13	80.92	149.56
Coal	31	80.26	131.39
Energy	16	42.79	98.67
Fertiliser	7	63.72	90.60
Mines	3	38.73	88.52
Industry	9	46.24	61.20
Communications	2	10.97	2.58
Surface transport	19	87.67	3.96
Petroleum and natural gas	10	53.51	4.80
Total	290	66.23	82.29

Cost overrun is calculated as the difference between actual cost at conclusion and budget, divided by the budget. To reassume the most important information, 64% of analysed projects had cost overruns and 56% had time overruns. Detailed data suggest that average cost overrun is 82% and average time overrun is 66%. Furthermore, Morris states that only 20-25% of projects that presented cost overruns were mainly influenced by unexpected inflation, while remaining 75-80% have to be explained in other terms.

2.2.2 The Flyvbjerg et al. study

Another interesting research was conducted focusing on public projects (Flyvbjerg et al., 2002). This research addresses 258 transportation infrastructure projects from all over the world and that cover a period of 70 years. A detailed statistical analysis was conducted, focusing on project costs and differences between budgets approved at sanction gate and final project costs.

Figure 2.1 shows a histogram with cost overruns and respective frequency. Table 2.3 gives information about cost deviation, based on types of projects and table 2.4 gives more detailed information about projects geographical locations. Tables represent average values for cost overruns and standard deviations of data of projects analysed in the research.

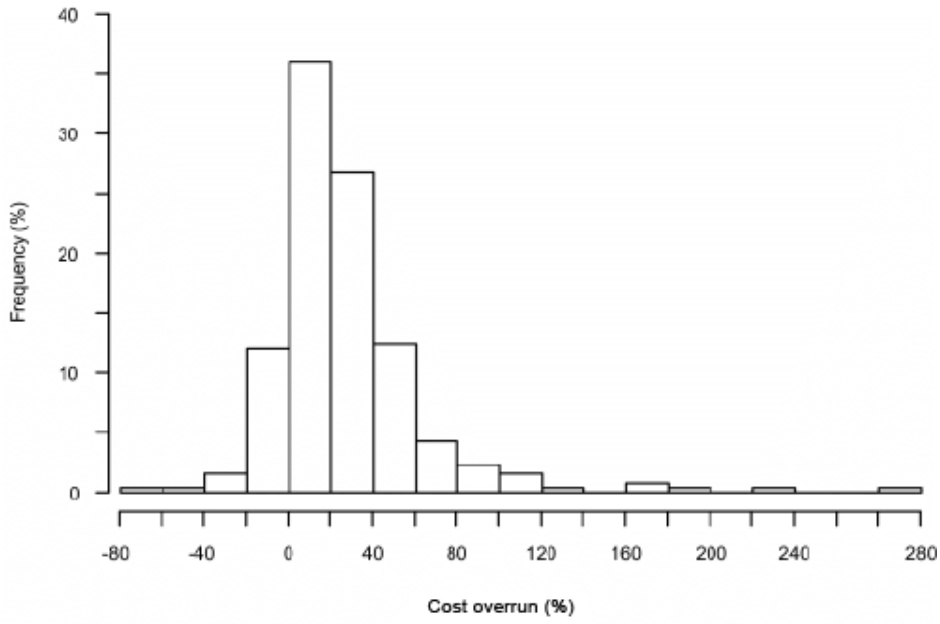

Figure 2.1

Table 2.3

Sector	**No of projects**	**Cost overrun [%]**	**St. deviation [%]**
Rail	58	44.7	38.4
Fixed links	33	33.8	62.4
Roads	167	20.4	29.9
Total	258	27.6	38.7

Table 2.4

Sector	Europe			North America			Other areas		
	No of proj.	Cost over. [%]	St. dev. [%]	No of proj.	Cost over. [%]	St. dev. [%]	No of proj.	Cost over. [%]	St. dev. [%]
Rail	23	34.2	25.1	19	40.8	36.8	16	64.6	49.5
Fixed links	15	43.4	52.0	18	25.7	70.5	0	-	-
Roads	143	22.4	24.9	24	8.4	49.4	0	-	-
Total	181	25.7	28.7	61	23.6	54.2	16	64.6	49.5

The most interesting data resulting from the statistical analysis conducted in the study are the followings:

- The calculated likelihood of actual cost being higher than estimated cost is 86%.
- Average cost overruns are 28%. This means that final costs are on average 28% higher with respect to the budgets.
- The hypothesis that the error of overestimating costs is as common as the error of underestimating is rejected ($p<0,001$).
- The hypothesis that the numerical size of the error of overestimating costs is the same as the numerical size of the error of underestimating costs is rejected ($p<0,001$).
- Reviewing cost data for other projects including power plants, dams, water distribution, oil and gas extraction, information technology systems, aerospace systems, and weapons systems; results show that also these kinds of projects are prone to cost underestimation
- Focusing on 111 projects distributed on a period approximately between 1910 and 2000, null hypothesis that year of decision has no effect on the difference between actual and estimated costs cannot be rejected ($p=0.22$). Figure 2.2 shows this trend. This means that errors have stayed constant during time.

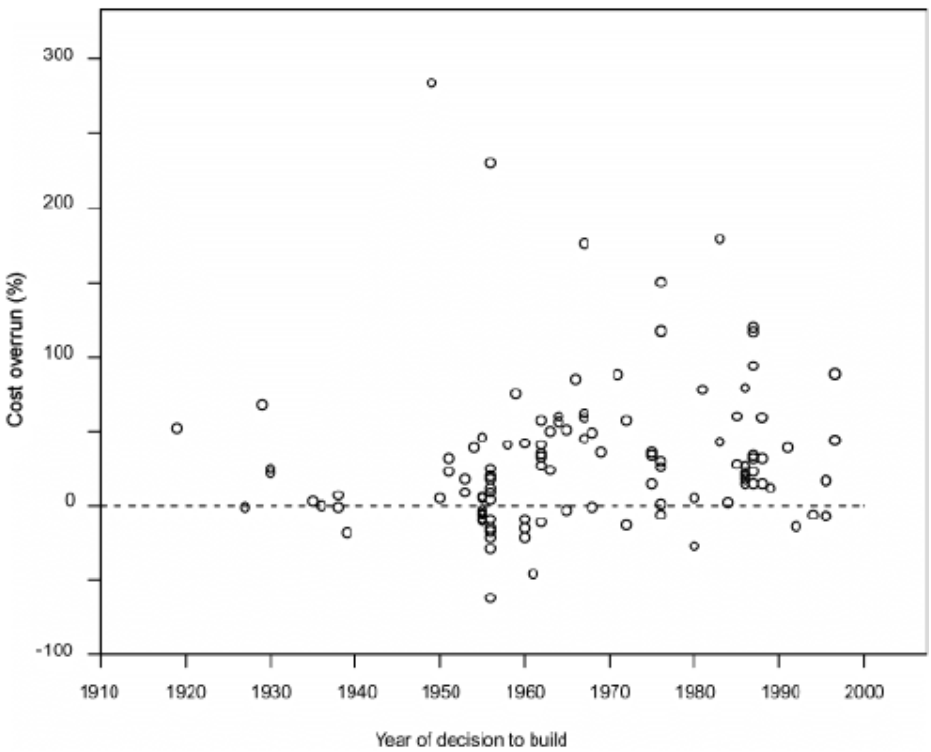

Figure 2.2

As a clear conclusion, the authors suggest that:

> *"the error of underestimating costs is significantly much more common and much larger than the error of overestimating costs. Underestimation of costs at the time of decision to build is the rule rather than the exception for transportation infrastructure projects. Frequent and substantial cost escalation is the result."*

2.3 Failure of industrial megaprojects

As previously said, a large research conducted by Independent Project Analysis is available, with a database regarding private industrial megaprojects. A study (Merrow, 2011) reports the most important information about analyses conducted on such database of 318 global industrial large projects, namely projects with budgets larger than $1 billion in 2010 U.S. dollars.

2.3.1 Megaprojects classification

The database of 318 industrial megaprojects contains projects from all industrial sectors and geographical distribution, these two categorizations are listed respectively in table 2.5 and 2.6.

Table 2.5

Industrial sector	**No of projects**	**Percent of sample [%]**
Oil and gas production	130	41
Petroleum processing and refining	66	21
Minerals and metals	47	15
Chemicals	31	10
Liquefied natural gas	24	8
Power generation	8	3
Pipelines	7	2
Others	5	2
Total	318	100

Table 2.6

Geographical area	**Percent of sample [%]**
South America	19
Europe	15
Middle East	15
USA	13
Africa	9
Asia	9
Oceania	9
Canada	7
Central Asia	4

2.3.2 Five dimensions for project failure

In this study the focus is not put principally on cost and time outcomes of the projects but rather on general success. The author states that there are no half measures in industrial megaprojects outcomes; they fall naturally into exceptionally good or exceptionally bad projects, with only very few in the middle. This pattern is significantly different from normal-sized projects, which are usually distributed with a big group of mediocre projects, according to the author.
To judge megaproject outcome, in order to separate successes from failures, the five aspects listed in table 2.7 are evaluated, with respective values that stand for the thresholds for failure.

Table 2.7

Failure dimension	**Threshold for failure**
Cost overruns	> 25%
Cost competitiveness	> 25%
Slip in execution schedule	> 25%
Schedule competitiveness	> 50%
Production versus plan	Significantly reduced production into year 2

Cost and schedule competitiveness measure expenditures and duration of the considered project in relation to similar projects. 'Production versus plan' stands for the production that the facility delivered by the project was planned to produce. Projects are considered successful if no one of the listed thresholds is exceeded, otherwise they are considered failures. Competitiveness and production versus plan are interesting aspects which however are not strictly related to the topics of the thesis. It is though possible to notice that cost and time overruns represent two crucial aspects to judge megaproject success.

The most relevant data of this study is the percentage of megaprojects that failed: 65%. More than half of the analysed projects exceeded the threshold of at least one of the failure dimensions. No detailed data are given about the megaprojects that presented cost and time overruns which passed the thresholds, however the author suggests that few of the projects failed only in one dimension; therefore it is possible to claim that a considerable number ended up with costs and duration that significantly exceeded budget and schedule.

2.4 Causes and explanations

Given the data presented in the previous sections, it is possible to notice that flaws in forecasting project cost and duration are a serious and important issue in project management. Successes (or failures) are related to high differences between estimates and final real outcomes (Merrow, 2011) and these types of errors are common and usual (figure 2.3).

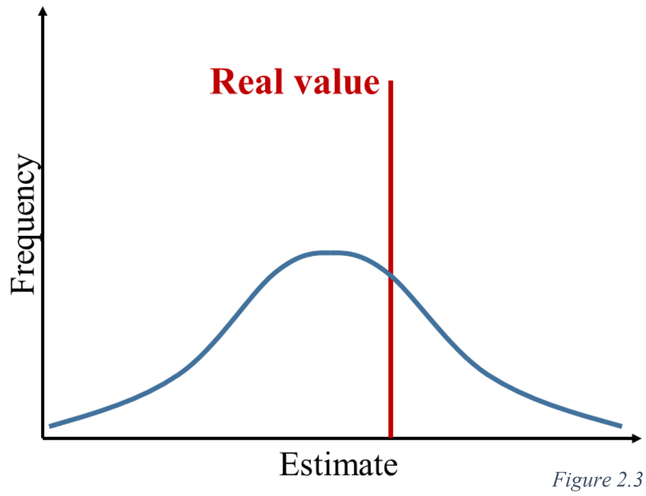

Figure 2.3

The importance of this problem obviously raises the necessity to investigate about possible solutions. Nevertheless, it is first important to understand the nature of these errors. A right assessment is inevitably the first step to permit, in the second scope, to find an adequate corrective procedure that can lead to more accurate estimates.

Understanding the nature of the presented flaws is the second aim of this thesis. Two general distinctions in addressing the differences between estimates and real outcome values can be made.
First, it is possible to distinguish between causes and explanations. Causes are referred to specific aspects about the project and its management, while explanations give a wider overview of general groups of similar causes (Cantarelli et al., 2010). For example, a specific psychological bias is related to the psychological explanations.
Second, a distinction can be made between the explanations concerning variances in performances during project execution phase, thus leading to outcomes

different form estimates, and lack of forecasting capability during planning and execution phase, thus leading to unreliable estimates that result into unattainable baselines and ineffective control, respectively before and after sanction gate

In this thesis the focus is put on explanations regarding lack of forecasting capability. Such explanations are divided in three categories that will be addressed in the three chapters that follow: technical, psychological and political-organisational explanations.

Chapter 3

Technical explanations

3.1 Technical errors in forecasting

In project management, estimates are the result of forecasting processes which imply the use of methods and techniques defined and developed within the organisations. Cost and time estimates (and related accuracies), both in planning and execution phase, are outputs of these processes, thus depending on used methodologies.
Technical errors concern imperfect techniques, inadequate data, honest mistakes and lack of experience that lead to inaccurate estimates (Flyvbjerg, 2009). In the literature, great importance is attached to these factors. The use of unreliable or outdated data and inappropriate forecasting models are seen as the most common reasons for poor forecasts (Vanston and Vanston, 2004). Consequently many efforts have been devoted to improve forecasting techniques and to find models that result into more reliable and accurate estimates.

3.2 Forecasting and risk management

The accuracy given for estimates is related to the uncertainty that characterizes the scenario in which a project develops. As planning phase advances, uncertainty decreases and accuracy increases, resulting in increasingly narrow ranges in which the outcome is predicted to fall. In executive phase, the same situation shows.

However uncertainty is a factor that cannot be completely eliminated in project management. There could always be events, which are not sure to occur, that can influence the project and its outcomes. These kinds of events are defined as 'risks'. The Project Management Institute (PMI, 2010) gives a clear and complete definition of project risk:

> *"Project risk is an uncertain event or condition that, if it occurs has a positive or negative impact on one or more project objectives such as scope, schedule, cost, and quality."*

Hence risks concern uncertain events that can have an impact on project outcomes. Risk can both negatively or positively affect the project, by the way it has been traditionally seen primarily in its negative sense (Caron, 2009).

Risks are intrinsic elements in projects (Caron, 2009). Risk management can be considered as the essence of project management (Turner, 2009). It is thus possible to understand that good risk management is the key to successful project and it plays a fundamental role in forecasts.

3.2.1 Risk management process

Risk management is not only one of the most important functions in project management. Due to its importance, it is also one of the major subjects of study in project management field. Many improvements regarding risk management techniques have been proposed during the last years, currently risk management is still a relevant and popular topic in order to reach forecasting methods advancements.
It is hence essential to give a brief, but exhaustive, description of risk management process, which is at the core of risk management (Turner, 2009).

Risk management process is a systematic and structured method to manage risks during the whole project life-cycle. A generic risk management process is made up of six phases (Figure 3.1):

- Risk Management Plan: it is the application of the organisation's methodologies to manage risks, applied to the single project. It defines activities and steps to follow such as approaches, tools and data sources; roles, responsibilities and schedules; procedures to prioritize risks, reporting formats and communication standards (PMI, 2010).

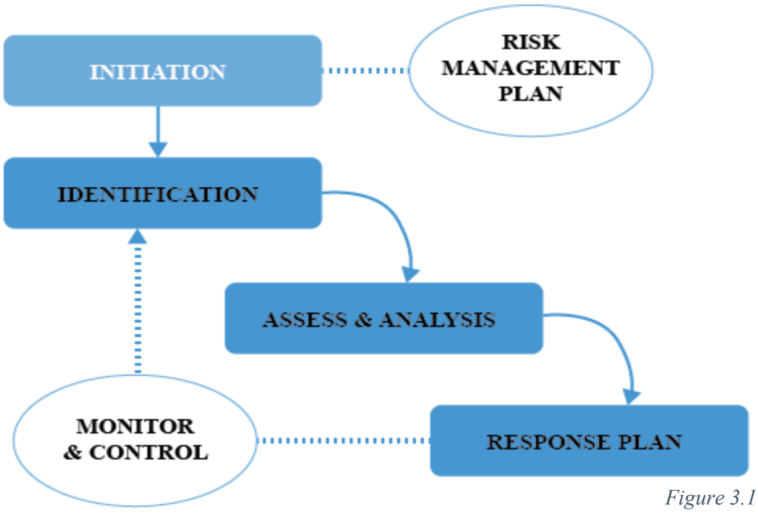

Figure 3.1

- Risk Identification: it is the phase that concerns determination and documentation of which risks may affect the project. For identifying risks, the main processes can be divided into two categories: creative processes, such as brainstorming and interviews, and mechanical processes (Turner, 2009). The output of this phase is the Risk Register, a document containing all the risk identified related to all the aspects of project development.

- Qualitative risk assessment: in this phase individual project risks are evaluated in order to determine their impact. The objective is to prioritize risk, so that it will be possible to focus further analysis and action on the most relevant ones. A likelihood/consequences matrix can give an overview on risk, showing which of them are the most significant (Figure 3.2).

Likelihood \ Impact	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med Hi	High	High
Likely	Low	Low Med	Medium	Med Hi	High
Possible	Low	Low Med	Medium	Med Hi	Med Hi
Unlikely	Low	Low Med	Low Med	Medium	Med Hi
Very Unlikely	Low	Low	Low Med	Medium	Medium

Figure 3.2

- Quantitative risk analysis: numerical estimates of the overall effects of risks can be provided, also considering risks simultaneously, using tools such as three-point estimating and Monte Carlo analysis (Turner, 2009).

- Risk response plan: a plan is developed in order to reduce threats and enhance opportunities. Considering threats reduction, there are three basic approaches that can be adopted. First one is avoidance, where the objective is it eliminate or substantially reduce the risk. Second one is deflection, where responsibility for financial impact of the risk is transferred to a third party. Third one is contingency, where an allowance is made for the risk (Turner, 2009).

- Risk monitor and control: during execution phase, risk response plan is implemented, identified risks are tracked and new ones are identified. The objective is to continuously optimize risks responses, thus implementing an iterative risk management process.

The process described is generic and agreed in broad terms by the principal literature sources (PMI, 2010; APM 2004; OGC, 2013). As previously said, many literature contribution can be found, which focus on specific aspects of risk management and propose technical improvements to forecasting process.

3.2.2 Critical issues in risk management

Though it is a well defined and systematic methodology, risk management process seems to be limited in some aspects of uncertainty consideration. One of the most critical issues is the poor consideration of risks relations that characterizes traditional risk management process (Ward and Chapman, 2003).

As previously stated, risk management focuses mainly on threats (risks with negative impact) with respect to opportunities (risks with positive impact). Without going into the details of possible limitations and related necessity of improvement of currently widespread methods, it is possible to realize how a leak in risk management affects forecasts.
Cost and time estimates are subsequently affected by any kind of weakness in risk management process and the signs point in the direction of underestimation of such outcomes. When something about risks, prevalently threats, is not considered, general perceived uncertainty about the project is downplayed and possible negative impacts are not taken into account. The inevitable consequences of such situation are downward errors in cost and time estimates.

3.3 Factors influencing estimates

If risk management process is maybe the most crucial aspect about forecasting methodologies and could be seen as the principal reason for technical errors, it is also important to address the problem of estimates accuracy focusing on which are the factors that can have a direct effect on execution phase performance, thus affecting predictability of cost and time outcomes. It is possible to say that such factors imply a higher uncertain project scenario and, consequently, increase the influence of risks on the project.

An interesting research found in literature analyses and compares the most important factors that can influence cost estimates for construction projects (Akintoye, 2000). Results show that the main factors are project complexity, scale and scope of construction, market condition, method of construction, site constraint, client's financial position, buildability and location of the project. Though this study was conducted focusing on construction field, it is possible to say that project complexity, which is the most relevant factor accounted for estimates influence, is widely shared in every project management application and is considered to affect both project duration and cost.

3.3.1 Project complexity

Since it is acknowledged as the most important factor influencing estimates, project complexity needs a brief introduction.
Complexity concerns high interaction between project components (Davies and Mackenzie, 2014). As shown in figure 3.3, the concept of complexity can be sub-divided into five main types, referred to five aspects of the project (Geraldi et al., 2011):

- Structural complexity: it is mainly related to three attributes of the project which are the project size, the variety and the number of interdependencies

- Uncertainty: this aspect is related to interaction between uncertain events

- Dynamics: it refers to changes in project functions or project scenario

- Pace: it is related to time constrains and necessity to concurrent engineering, that can lead to higher interdependencies

- Socio-political complexity: it concerns aspects of potential conflicting interests and difficult personalities.

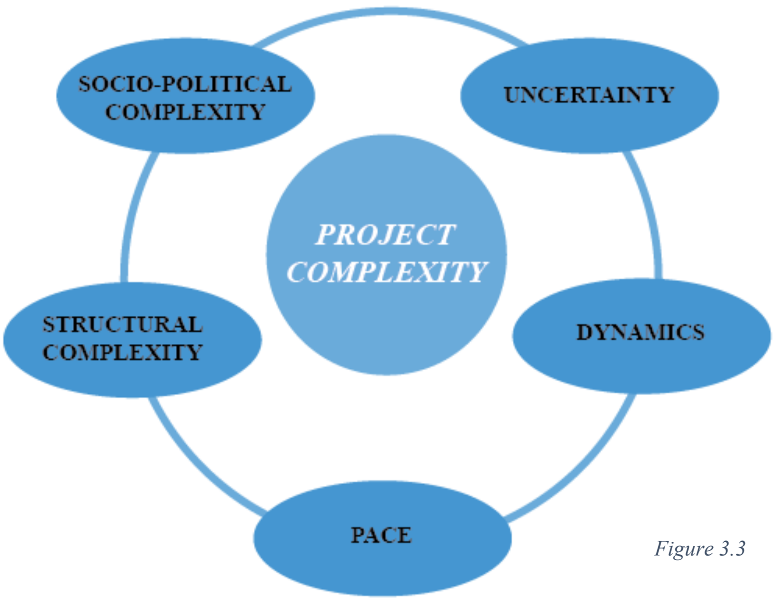

Figure 3.3

3.4 Technical errors influence on estimates

To sum up what previously addressed, it is possible to conclude that risk management is the most relevant aspect about forecasting methodologies that leads to inaccurate estimates. In addition, project complexity is the most important factor that influences cost and time estimates.
Consequently, technical errors strongly depend on imperfections in risk management process and are highly affected by project complexity. This means that forecasting the outcomes of complex projects and complex megaprojects is a process that results in less accurate estimates and risk management process is probably the most relevant source of technological errors.

Once understood the nature of technical errors, it is interesting to comprehend how such errors explain flawed estimates.
It is important to make three assumptions that come from the literature and are fundamental to introduce the assessment of technical explanations.
First consideration concerns the development of projects and project management during the last years. Projects are becoming increasingly important and formalised, being the core to always more organisations (Geraldi et al., 2011). This can suggest that the continuous strive towards project-based management has led to a consequent growth of project complexity. The more organisations try to achieve changes and earn revenues through projects, the more projects become complex.
Second consideration is about the lack of improvement in forecasting project costs and duration in the past years. According to researches already presented in the previous chapter (Canatarelli et al., 2010), differences between cost and time estimates and final values after completion seem to stay constant and withstand the passage of time. This situation doesn't meet the expectation of continuous improvements in professional settings, where errors and their causes are recognized and mitigated through the refinement of data and methods (Flyvbjerg, 2011).
Third consideration still relates data presented in the previous chapters. Estimate errors distribution is biased, with a general tendency to cost and time underestimation.

A first logical conclusion can be drawn considering the first two assumptions: improvements in forecasting may have been balanced by complexity increasing, resulting in continuously constant errors. This can suggest that technical errors can be an exhaustive explanation to forecasting errors.
However technical errors explain inaccuracy in estimates but not a biased distribution. For this kind of errors, a distribution around zero would be expected (Flyvbjerg, 2011). Even if technical errors can be seen as consequences mainly of limited risk management, a reduction of systematic errors in estimates during time

would be expected.
As a final conclusion, it is possible to state that technical errors only partially explain flaws in forecasting. A further effort in investigating psychological and political-organisational causes is needed to better assess the problem.

Chapter 4

Psychological explanations

4.1 Forecasting under uncertainty

Projects are characterized by uniqueness and novelty. In such situations uncertainty plays a fundamental role. There is no project without uncertainty and megaprojects are consequently symbolized by highly uncertain scenarios.

Forecasting processes are hence affected by uncertainty, as already explained in the previous chapter, resulting in planned costs and durations which should consider all the factors that are not sure to happen and may influence the outcome. The activity of forecasting will then unavoidably involve large component of judgement and intuition. The opinions of people involved in this activity are the source of many technological, political and social forecasts and will certainly affect final planned values. Even where rigorous mathematical models or simulations are used, opinions and intuitions play an important part in the process that determines planned values (Kahneman and Tversky, 1977).

4.2 Use of knowledge in forecasting

Another important aspect is the use of knowledge in the forecasting process. In uncertain or high uncertain situations, in order to enhance forecasts, there's the tendency to use every knowledge source that could effectively help to reach more reliable estimates.

Generally, the knowledge sources can be divided into two categories: explicit and tacit. Explicit knowledge is related to all the data records available and suitable for the specific project considered. Tacit knowledge corresponds to experts' judgements and opinions about the development of the project. It is possible to further divide this kind of knowledge into two different areas: internal and external. Tacit internal knowledge concerns experts' intuitions about possible situations and events that can influence the project's execution, while tacit external knowledge regards the experts' experience about past projects and the identification of analogies between them and the current project (Caron, 2013).

It is possible to realize that harvesting all the knowledge sources available is fundamental to the forecasting process. Exploiting experts' opinions and intuitions becomes increasingly important in high uncertainty project scenarios. Hence estimates, and consequently their reliability, are influenced by subjective components which strictly depend on mental processes made by practitioners that give their contribution to forecasts.

4.3 Planning fallacy

According to studies conducted by Kahneman and Tversky, subjective contributions to forecasting project outcomes can be traced back to judgement under conditions of uncertainty.
From researches conducted in this field, there are two aspects that emerge which are relevant to the present concern. First, people make errors of judgement that are systematic rather than random, manifesting bias rather than confusion. Second, experts and laymen make many common errors, sharing same biases (Kahneman and Tversky, 1977).
Results show that in uncertainty situations people are excessively inclined to consider problems as unique, focusing on the constituents of the current project. Though in many forecasting problems finding past similar situations can be difficult, it is often possible to define a distribution of information regarding previous experiences. However people seem to be insufficiently sensitive to distributional data and isolate the aspect they are considering. This tendency is amplified by any factor which increases the sense of uniqueness of the problem (Kahneman and Tversky, 1977; Kahneman and Lovallo, 1993).

The consequence of this inclination is that the contribution to estimates given by tacit internal knowledge is far greater the contribution given by tacit external knowledge. Lovallo and Kahneman suggest that this trend, called 'internal approach' or 'inside view', can cause an unfounded overoptimism and is likely to produce biased estimates (Lovallo and Kahneman, 2003):

> *"When forecasting the outcomes of risky projects, executives all too easily fall victim to what psychologists call the planning fallacy. In its grip, managers make decisions based on delusional optimism rather than on a rationale weighting*

of gain, losses, and probabilities. They overestimate benefits and underestimate costs. They spin scenarios of success while overlooking the potential for mistakes and miscalculation"

'Planning fallacy' is hence related to overoptimism which causes systematic errors in forecasting project outcomes during planning phase. In particular, project cost and duration estimates are affected by this tendency, resulting in unrealistic planned values. Consequently projects will easily end up with cost overruns and delays.

4.4 Sustained false optimism in execution phase

False optimism is present not only during the planning phase of the project but also during project implementation. Once the project execution phase has started, many different techniques like Earned Value Management and Earned Schedule can be used to compare performances to planned values, relying on cost and time performance indicators. Though these techniques give objective information about project implementation performance against the plan, indicators aren't always reliable and practitioners tend to count mainly on their intuition, especially in the first stages of project execution.
A research available in literature shows the persistence of this phenomenon beyond the planning phase and into the execution phase, resulting in the termed 'sustained false optimism' or 'on-going false optimism' (Kutsch et al., 2011).

4.5 Cognitive biases

The phenomenon previously described is broadly analysed in the literature and generally known as 'optimism bias'. In the current chapter this phenomenon is addressed from the psychological point of view, assessing the errors in the way the mind processes information. It is of great importance to point up that this behaviour is subconscious, leading to unaware systematic errors.

Overoptimism in forecasting project outcomes during planning and execution phase can be traced to the following cognitive biases:

- Egocentricity bias
- Outcome attribution
- Confirmation

- Availability
- Representativeness
- Anchoring and adjustment
- Paradox of dispositional optimism
- False consensus and competitor neglect

4.5.1 Egocentricity bias

Practitioners are prone to the illusion that they are in control. They tend to overestimate the degree of control they have over events, exaggerating their personal abilities. This self-confidence can lead individuals to think that they will be able to easily overcome negative aspects and possible problems during the project execution phase. This kind of misperception leads to deny, or at least underestimate, the role of chance in the outcomes of plans and believe that people have a capacity to guide projects towards a desirable outcome which is greater than warranted by objectivity (Lovallo and Kahneman, 2003; Jaafari, 2001). This cognitive bias is known as 'egocentricity bias' (Smith, 2007).

During planning phase, egocentricity bias affects forecasts in terms of risk perception and consideration. Practitioners tend to treat risks as challenges and believe that results are regulated mainly by their own action. Possible negative events are seen as obstacles to be overcome by the exercise of skill (Kahneman and Lovallo 1993). This approach causes to partially, or even completely, ignore possible effects of random and uncontrollable events. As a direct consequence, estimates of cost and time are overoptimistic.

Egocentricity bias doesn't end with the end of planning phase. When it comes to implementing the project, this bias still affects estimates to completion in the same way described for planning phase. Practitioners don't attach much importance to possible negative information about execution trends given by cost and time EVM indicators, believing their own actions and decision could give a boost to improve initially poor performances (Kutsch et al., 2011).

4.5.2 Outcome attribution

Individuals tend to ascribe successful and unsuccessful results of managed issues to different causes. Typically people take credit for positive outcomes and blame someone or something else for negative outcomes, no matter what is the real cause. This misperception of causes leads to record past experiences in the following way: successes are attributed to internal factors such as personal skills, while failures are attributed to external factors like unlucky circumstances. This particular behaviour is termed ‘outcome attribution’ (Kutsch et al., 2011).

It is logical to realize that this kind of bias acts both in planning and execution phase. As previously said, the use of tacit knowledge in forecasting in unbalanced: tacit internal knowledge tends to prevail on external. Following the pattern of outcome attribution bias and unbalanced use of tacit knowledge, it is possible to understand how past experiences factor into planning phase and execution phase estimates. Scarce use of tacit external knowledge implies poor consideration of past experiences, such experiences are even less considered when they are related to unsuccessful events, as their failure is attributed to external causes. As a consequence, estimates suffer from overoptimism since future scenarios are seen less risky than suggested by past similar events (Pinto, 2013).

4.5.3 Confirmation bias

Individuals tend to give more importance to information that confirm their pre-existing beliefs. In psychology this tendency is known as ‘confirmation bias’ or ‘confirmatory bias’. This bias displays when people recall information selectively or when they interpret it in a partial way. People also tend to consider ambiguous information as supporting their existing position (Plous, 1993).

In project management field, this bias can influence both planning and execution phase forecasts, depending on practitioners’ attitudes to the projects itself. It is important to understand the initial approach and personal beliefs of people involved in the different project phases. Confirmation bias strongly depends on what individuals personally and sincerely believe about the project and its outcomes. If a person responsible for planning phase estimates thinks the project is a good project and it will end up with successful outcomes or will be unlikely to face difficult situations, confirmation bias can influence the forecasts, leading him or her to recall information, on which estimates will be based, that support his own opinion.
During execution phase the same situation can show. People responsible for project implementation, when it comes to compare performance to the plan, will recall mainly information that confirm what they think about future performance and developments.

Hence in case of practitioners’ pre-existing optimism attitude on the project, cost and time estimates can be overoptimistic, as the result of processed information which were gathered in presence of confirmation bias.

4.5.6 Availability

In psychology, availability is not defined as a cognitive bias but as a judgement heuristic. Heuristics are mental shortcuts that individuals often use for judgements or decision making. In this heuristic, people make decisions relying upon information that easily recall personal experience, rather than objectively examine other alternatives or procedures. Reliance on availability can lead to predictable biases (Tversky and Kahneman, 1975).

It is intuitive to say how, in project management, biases due availability heuristic depend on practitioners' experience. Estimates in planning phase can be influenced by a particular event or situation which left a strong impression on people involved in forecasting process. The same could occur for estimates during execution phase. In forecasting project outcomes, people can rely on information easily available in their mind that can be related to current scenario. It is important to underline that information recalled relying on availability heuristic aren't necessarily related to past experiences similar to the current project. Biases due to availability heuristics don't concern similarity between current situation recalled information used to support estimated, but importance and strength with which such information are fixed in the mind.

4.5.7 Representativeness

Representativeness in another judgement heuristic that can lead to biases. This heuristic is defined as "the degree to which an event is similar in essential characteristic to its parent population, and reflects the salient features of the process by which it is generated". Relying on representativeness to make decision can cause to judge wrongly, as the fact that something could be more representative doesn't mean that it is more likely. In addition, the confidence that people have on their judgements and decision will depend mainly on the degree of representativeness (Tversky and Kahneman, 1975).

When making forecasts, both in project planning and execution phase, people can fall victim to biases due to representativeness heuristic. In forecasting values like costs and durations, inputs from different information are considered. Estimates are the outcome of an inputs evaluation process. Representativeness heuristic lead people to often predict by selecting the outcome that is most representative of inputs (Tversky and Kahneman, 1975). This way individuals can be misled perhaps by framework conditions like a positive trend of outcomes of project that were developed in the same geographical area and in the same industrial field of current project, or successful results obtained in past project by team members.

4.5.8 Anchoring and adjustment

People tend to rely too strongly on the first information they have about a problem. Starting from an initial value, suggested by the formulation of the problem or by partial considerations about initial knowledge, changes are made as more information are gathered and level of knowledge increases. The problem is that changes to the initial value tend to be insufficient and the final estimate sticks too much to the starting value.
Anchoring and adjustment, as availability and representativeness, is a judgement heuristic which logically leads to biased decisions. Initial information about the problem considered become unintentionally of much greater importance than further information, only because the formers are the first impression about the problem to be fixed in the mind. Hence the first estimate acts like an anchor that is consequently moved only a little with respect to the relevance of further knowledge gained.
According to studies conducted by Tversky and Kahneman, anchoring occurs both when first estimate is made by the subjects who will have to make successive adjustments and when the starting value is directly given to the same subjects (Tversky and Kahneman, 1975).

Anchoring and adjustment is probably the most powerful heuristic in judgement in high uncertainty situations. Bias due to this heuristic is then of great relevance and project management is a typical field where it can display. In planning phase first stages raw estimates about project cost and duration are made. These estimates present a very low grade of accuracy as few information are known about the project. Further estimates, with increasingly higher levels of accuracy, are made reviewing previous stages values. As explained, initial raw estimate acts like the anchor for first revision and this patterns continues until the project approval.
This bias affects also estimates during execution phase. The anchor here is represented by the budget value and total duration approved in the sanction gate. Information collected during implementation will give indications about the performance that can evidence that the projects is likely to end up with cost overruns or delays. Changes to planned values, if made, will stay however near to the anchor.

4.5.9 Paradox of dispositional optimism

Dispositional optimism is defined as the tendency to expect that more desirable things than undesirable will happen in the future (Scheier and Carver, 1985). Studies suggest that people that are high in dispositional optimism have good ability in finding suitable goals and great confidence in achieving them. However when fixed goals become unattainable, they stay committed to them or completely give up on the project, without making changes to the first target (Jemison, 1987).

It is possible to understand that this behaviour in project management can cause problems, especially during execution phase when performances don't meet planned trends.

4.5.10 False consensus and competitor neglect

The phenomenon of false consensus bias describes people's tendency to project their way of thinking onto others, believing other people think the same way as they do. Individuals are prone to see their own behavioural choices and judgments as relatively common and appropriate to circumstances without knowing others' opinion (Ross et al., 1977).
Competitor neglect accounts for individuals' tendency to focus on their own skills and their own organization's capabilities, thus neglecting the potential abilities and actions of possible business rivals.

In project management these two biases can affect primarily stakeholders analysis. False consensus can be projected between team members as well, but it would be mitigated and eliminated with discussions and meetings, which are much more frequent inside project team than between the team and other stakeholders.
The first, and maybe most important, distinction about stakeholders is whether they are for or against the project. Stakeholders are hence subdivided into positive and negative, with respect to their position about project outcomes (Turner, 2009). False consensus can cause to superficially think that stakeholders considered in favour of the project are actually for it, and to take for granted their support.
Competitor neglect bias can lead to underestimate the influence that negative stakeholders can have on the outcome of the project.

4.6 Cognitive biases influence on estimates

In literature cognitive biases are accounted to be one of the most important causes for errors in forecasting project outcomes. As previously seen estimates are affected by subjective factors due to the use of tacit knowledge. Cognitive biases can display in the use of such knowledge and in taking final decisions about estimates values.
However presence and influence of these biases depend on attitudes and psychological factors of people involved in forecasting process. It is possible that only some or no-one of the biases previously described display, depending on

who is responsible for the forecasts. A specific bias can influence planning phase estimates and doesn't affect execution phase.

It is interesting to understand whether a bias can accentuate the effect of another. Some of the cognitive biases described, due to their nature, depend on psychological conditions that may concern some other biases. Therefore there could be relations between biases.

Focusing on their definition, it is possible to propose a general causal dependency of cognitive biases. The biases that may create an original overoptimistic approach are egocentricity bias, outcome attribution and paradox of dispositional optimism. These three depend mainly on psychological characteristics of people involved in forecasts and can be defined as 'primitive biases'.

The presence of one or more of primitive biases can cause a stronger effect of the other biases due to an unreasonable optimistic approach. In this way first estimates, which represent the initial anchor in anchoring and adjustment phenomenon, will be affected by all primitive biases and successively adjustments will suffer primarily from paradox of dispositional optimism.

Confirmation and representativeness as well can be conditioned by primitive biases, as an overoptimistic opinion would influence the knowledge used to make estimates, increasing the importance of information that confirm and better represent pre-existing optimism.

False consensus can be also affected by primitive biases, as personal unfounded opinion can be projected to stakeholders.

Instead availability and competitor neglect can be seen as generally independent from other biases.

In the figure 4.1 the pattern of biases interaction is shown. It is important to point up that the presented dependencies are related to the general nature of cognitive biases. In particular cases the proposed pattern accounts for possible biases interactions, which will however mainly depend on people involved.

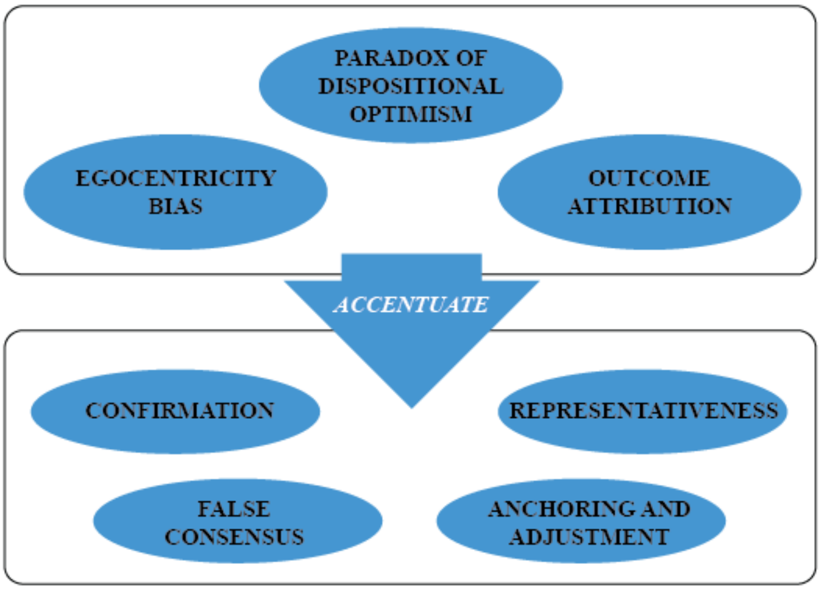
PARADOX OF
DISPOSITIONAL
OPTIMISM
EGOCENTRICITY
BIAS
OUTCOME
ATTRIBUTION
ACCENTUATE
CONFIRMATION
REPRESENTATIVENESS
FALSE
CONSENSUS
ANCHORING AND
ADJUSTMENT

Figure 4.1

Chapter 5

Political and organisational explanations

5.1 Conscious misrepresentation

In the previous chapter the issue of biased and overoptimistic estimates has been addressed from the psychological point of view, assessing the causes of unintentional misrepresented forecasts.

Another interpretation of biased estimates has been proposed in the literature, especially in the last few years (Flyvbjerg, 2005, 2006, 2009, 2011; Flyvbjerg et al., 2002; Flyvbjerg and COWI, 2004; Pinto, 2013; Wachs, 1989), which explains forecasting errors in terms of intentional and strategic misrepresentation. In this way, cost and duration underestimations are seen as consequence of deliberate intentions to "spin scenarios of success and gloss over the potential for failure" (Flyvbjerg, 2009). According to these authors, forecasting processes are influenced by interests to get projects approved. This leads to estimates where beneficial outcomes are deliberately overestimated and costs, and consequently durations, are deliberately underestimated in order to increase the chance to pass the project sanction gate. These motivations are presented as 'political and organisational explanations'. The use of the terms 'political' and organisational' will be further explained.

Political and organisational explanations account well for systematic errors in cost and duration estimates. It is logical to understand how this kind of strategic misrepresentation leads to cost and duration underestimation.

The difficult issue about such explanations is trying to demonstrate (or at least assess) them. Flyvbjerg suggests that (Flyvbjerg, 2009):

> *"A key question for explanations in terms of strategic misrepresentation is whether estimates of costs and benefits are intentionally biased [...]. This question raises the difficult issue of lying. Questions of lying are notoriously hard to*

answer, because by definition a lie consist in making a statement intended to deceive others, and in order to establish whether lying has taken place, one must therefore know the intentions of actors. […] if promoters and managers have intentionally cooked estimates of costs and benefits to get a project started, they are unlikely to tell researchers or others formally that is the case."

However two researches in the literature succeeded in demonstrating this lying attitude (Flyvbjerg and COWI, 2004; Wachs, 1990).
Therefore flawed estimates can be caused by the presence of such attitude, leading to systematic reductions of cost and duration forecasted values. Such reductions are consciously made, knowing that all the inputs given to forecasts suggest that the cost and duration outcomes of the considered project will be likely to exceed the estimates.

As previously said, the goal of strategic misrepresentations is to achieve project approval. Practitioners lie with estimates in order to make the project they want to be implemented look better than suggested by an objective analysis. Hence it is possible to understand that the crucial times, when estimates can be affected by these voluntary underestimations, coincide with the end of the planning phase and the run-up to the sanction gate.

5.2 Pressures leading to strategic misrepresentation

It stands to reason that a project that looks better has more chances to be approved and pass to execution phase. However the direct consequence to such situation is that misrepresented estimates become cost and time objectives difficult to achieve. The project will be likely to suffer from cost overruns and time delays and finally the possibility of ending up with a failure increases.
Consequently strategic misrepresentations increase probabilities of failures and, in addition, are ethical breaches for professionals involved in forecasting process. Hence an obvious question that comes to mind is about the causes that lead practitioners to deliberately lie and adjust estimates.

As explained in the previous chapters, projects are becoming increasingly important. Such continuous development of project-based business has also led to an increased competition between projects. Not every project passes the sanction gate and project plans are used to prove that the considered project is the best choice in a given situation (Wachs, 1989).
Consequently strategic misrepresentation can be traced to agency problems and

political and organisational pressures (Flyvbjerg, 2009). Pressures to get a particular project, which competes with others, approved are the cause of intentional flaws in forecasting cost and duration outcomes.

It is important to distinguish between two different types of competition between projects. First, different project proposals can compete for the realisation of one specific project. In such situations of competitive bidding, only one proposal wins the contract and this is the typical case of public bids. Pressures related to this type of competition are defined as 'political pressures'.
Second, different proposals related to different projects can compete against each other, as funds and personnel available are limited and don't permit the execution of every project proposed inside the organisation; even if all the projects can be initially considered beneficial to the organisation, only the most valuables ones will pass the sanction gate. This is a typical situation that can show in a project-based organisation, hence pressures related to this type of competition are defined as 'organisational pressures'.

5.2.1 Political pressures

In case of competitive bidding, project promoters have the interest to secure approval and funding for their project. A study in literature (Flyvbjerg and COWI, 2004) demonstrated that such interest can lead to intentional cost and duration underestimations, using the formula shown in figure 5.1 in order to present the project as favourably as possible:

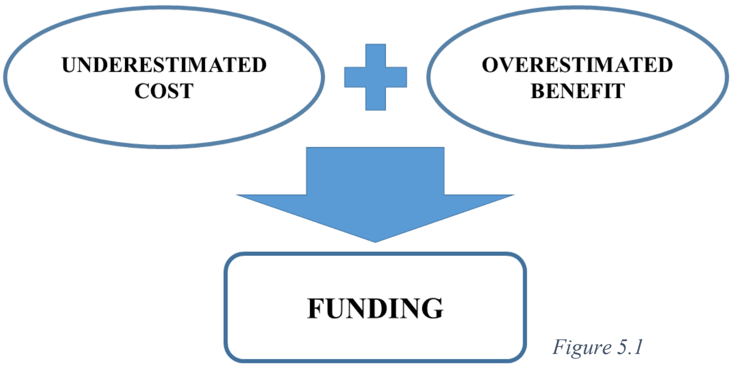

Figure 5.1

Generally, in public bids, project promoters or other actors who have an interest in project approval are not directly involved in forecasting process. However estimates are affected by such interest, as suggested by an interviewee conducted during an interview (Flyvbjerg and COWI2004):

"You will often as a planner know the real costs. You know that the budget is too low but it is difficult to pass such a message to the counsellors [politicians] and the private actors. They know that high costs reduce the chances of national funding."

Depending on the project and on the type of contract, different stakeholders, who can directly or indirectly influence the estimates, have interest in underestimating cost and duration outcomes. These interests and incentives to get the project approved are predominant with respect to interest to have reasonable budget and schedule (Flyvbjerg et al., 2009) and this is the cause of strategic misrepresentation.

To resume political pressures, present the followings are considered as the main sources of strategic deception (Flyvbjerg et al., 2009), under these conditions systematic misrepresentations are more likely:

- Self-interest: many stakeholders like contractors, engineers, bankers, lawyers and politicians have wide incentives as the project goes forward. The involvement or influence of such actors in the forecasting process can lead to systematic and strategic underestimations.

- Asymmetric information: the agent that champions the project has information that the principal, who is the ultimate decision maker, does not. Often, and especially in public projects, agents (could be a local government), officials, planners, and consultants are better informed, have stronger incentives to present project cost and benefit as favourably as possible and are more involved in forecasting process with respect to the principal (could be the state government). The consequence is that the principal takes decision based on the agents' interests.

- Different risk preferences: if the principal is risk averse, the agent submitting a proposal may downplay the risks influencing the project, in order to increase the chances to convince the principal.

- Different time horizons: this issue is typical of large public projects, where agents (primarily politicians) take decisions being concerned about personal interests that are related to the immediate future, a shorter term with respect to the entire project duration.

- Diffuse or asymmetric accountability: when responsibility for ultimate success or failure of the project is shared by different agents, it can be difficult that one of them could be held accountable for a bad outcome. This can lead to promote projects that protect agents from being held accountable for failures and not projects that maximise final benefits.

5.2.2 Organisational pressures

The pressures previously presented are typical of public projects, however they can show in presence of conditions similar to the ones describes above, also in private organisations. What is more common in these organisations is competitions between different projects related to different scopes.
It is difficult to find a general pattern of strategic misrepresentation under condition of organisational pressures, as every organisation has its own procedure for project planning and approval; in the literature it is hard to find sources concerning this problem.
However conditions that can generally lead to cost and time underestimations are related to interests in getting a project approved and winning a competition against other projects. This can be traced to incentives for project managers or other actors in implementing a specific project or jockeying for positions inside the organisation (Flyvbjerg, 2009). If such incentives are more appealing with respect to presenting reliable forecasts, systematic misrepresentation can affect the estimates.

5.2.3 Lack of interest in avoiding biased estimates

The situation previously depicted reveals that biased forecasts can be effective as they advocate the execution of the considered project (Wachs, 1989). As a consequence, too many projects proceed that should not and many other projects do not proceed that probably should (Flyvbjerg, 2009).
The problem of strategic misrepresentation may be present every time incentives to get a project approved for people directly or indirectly involved in forecasts are more relevant than incentives to have accountable estimates. Effectiveness of forecasts is then assessed on the basis of involved practitioners' personal profits and opportunities and not on the basis of organisation's possible benefits.
Where this problem shows, there is evidence that people involved are not enough committed to the project goals or even to the organisation's goals. Consequently practitioners look primarily on their own ambitions and, if they can get a personal advantage in getting a project executed, they may do whatever it takes to make it happen.

In a scenario with the conditions just described, few actors have a direct interest in avoiding systematic errors. In public projects this is a typical situation (Flyvbjerg and COWI, 2004). Accountable estimates don't pay off, while strategic misrepresentation do. Furthermore, people who can get advantage from implementing projects based on biased estimates aren't commonly responsible for subsequent cost overruns and delays; especially in public projects re-contracting in often possible and delays will be tolerated (Flyvbjerg et al., 2009).

5.3 Strategic misrepresentation influence on estimates

As stated in the beginning of this chapter, political and organisational explanations account well for systematic underestimations of project cost and duration. It is logical to understand that strategic misrepresentation lead to estimates that are lower than what can be objectively expected and this can cause a systematic difference between estimates and final values after project completions.

It is interesting to assess possible relative strength of political and organisational explanations and psychological explanations. Such explanations are complementary rather than alternative (Flyvbjerg, 2006). As shown in figure 5.2, in situations of strong political and organisational pressures, strategic misrepresentation account more than cognitive biases for forecasting errors. On the contrary, if pressures are low, explanations in terms of cognitive biases have their relative merit.

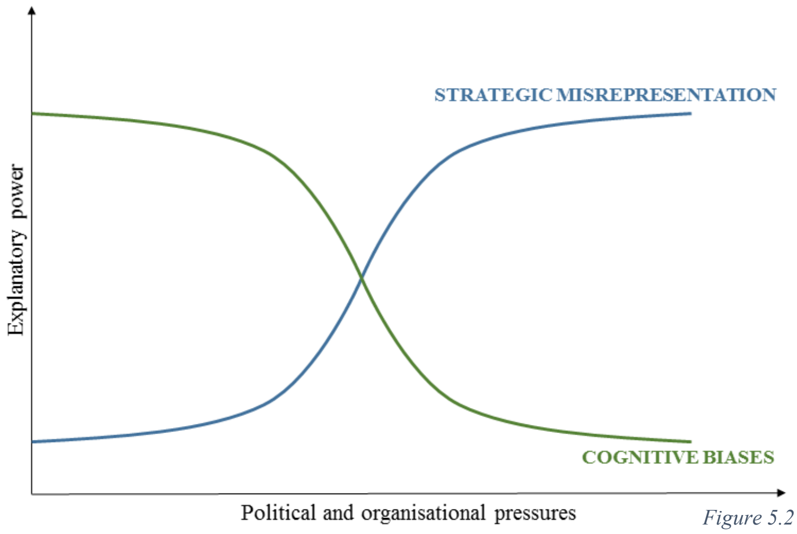

Figure 5.2

Chapter 6

Methods to improve forecasts

6.1 Need for bias reduction

In the previous chapters, forecasting methods and estimates, errors and explanations have been addressed. In the first two chapters, the most important aspects that emerge are the cruciality of cost and duration estimates to the entire project management and the tendency to make systematic errors in forecasts, underestimating project cost and duration. Afterwards, explanations to flawed forecasts have been approached.
In the path proposed by the issues tackled this far, the step that follows is to meet the challenge of improving forecasts. Such challenge, as already mentioned in the previous chapters, is one of the most critical and key aspects in project management scenario. Projects are characterized by uniqueness, novelty, rising complexity: all these factors, already pointed out, enhance the relevance of a need for continuous forecasting improvement. As a matter of fact, the challenge of improving estimates reliability is a major objective both in academic studies and in industrial efforts.

Forecasting improvement is a broad subject. There are many ways to deal with such issue, focusing for instance on a specific phase of the project or on a specific project outcome. Considering the forecasts subject of this thesis, concentrating then on cost and duration, it is important to make a statement to introduce and better understand the topics addressed in this chapter: distinction between the two key parameters relative to errors: dispersion and systematic errors. Such parameters are evaluated analysing data records of past and completed projects (Figure 6.1).

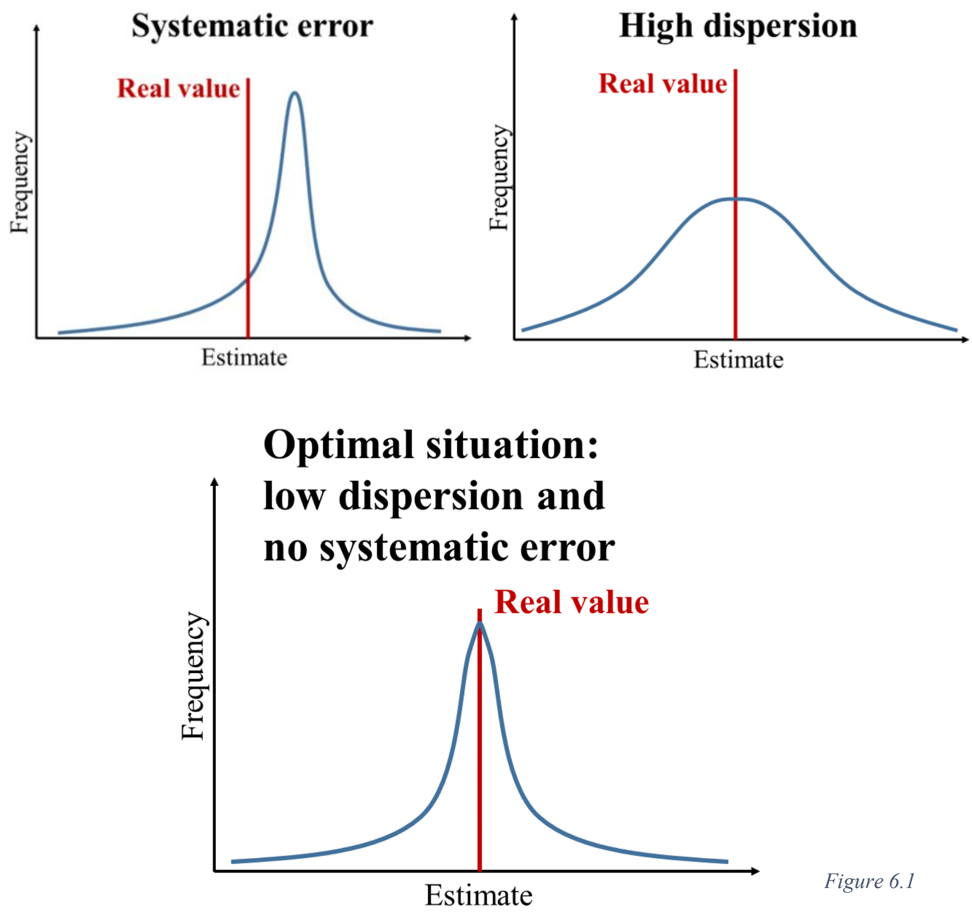

Figure 6.1

Basing on dispersion and systematic errors relative to past projects, assumptions can be made about future forecasts. From a statistical point of view, low dispersion means having a low standard deviation, while low systematic error means having a mean difference value near to zero. If past trends suggest that there is a high dispersion, future estimates can be considered as likely to present the same trend. These estimates are defined as characterized by a low level of confidence. On the other hand, if past trends present systematic errors, future estimates are likely to have the same problem being characterized by what is now defined as low precision.

Obviously the purpose of obtaining reliable estimates concerns improving both confidence and precision. Improving these two aspects means focusing on different factors and proceeding in different ways.

6.1.1 Obtaining confident estimates

As already mentioned in chapter 3, technical explanations account for trends of differences between estimates and real values that show a widely dispersed distribution. It is logical to think how an improper forecasting methodology results into an unconfident estimate. Improper methodologies regard inappropriate forecasting techniques and, consequently, imply a wide confidence range. Forecasted value is typically provided with a confidence expressed by a percentage of the value itself. This means that the difference between the maximum and the minimum expected value is estimated to be equal to the given confidence.
To have a touchstone, confidence at sanction gate is usually between 5% and 10%. Assuming that confidence of a certain cost estimate is 5%, this means that the difference between estimated cost and real cost should be maximum 2,5% of the estimated cost, as real value should be 2,5% higher or lower than the estimate, as shown in figure 6.2

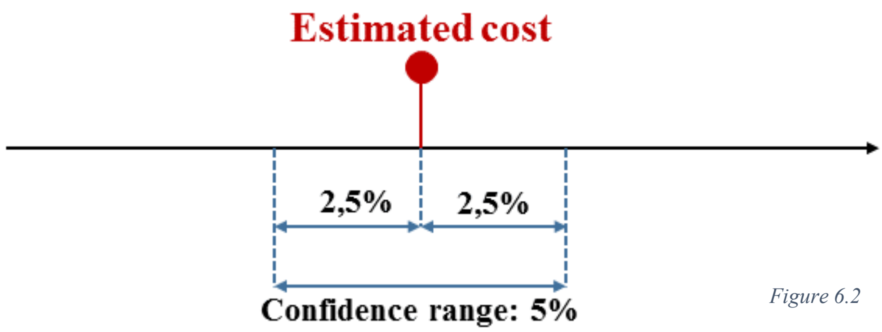

Figure 6.2

Hopefully the real value should fall inside the confidence range, assuming a random value included in such range. Therefore it is possible to understand how a scarce forecasting technique reflects in higher randomness, which means a higher confidence range, namely unconfident estimate. Improve forecasting techniques is the way to go in order to obtain more confident estimates. This is possible by correcting technical errors and refining forecasting procedures.

In the literature great importance is given to technical improvements and refinements in forecasting procedures, as already said in chapter 3. However the focus of this thesis is on systematic rather than casual errors. Therefore the attention will be on how reducing flaws concerning biased estimates.

6.1.2 Obtaining precise estimates

The second chapter of this thesis explained how a recurring problem of forecasts is the tendency to underestimation. In the chapters that followed psychological and political-organisational explanations appear to be the best accounting reasons for such tendency, besides a possible implication of lacks in risk management. Therefore problems that cause systematic errors regard mainly subjective components and tacit knowledge used in forecasting processes.
In order to obtain precise estimates it is necessary to deal with psychological and political-organisational problems; this means that forecasting methods should be refined from a qualitative point of view, trying to reduce, or at least eliminate, flaws.

In the literature, methods that deal with psychological and political-organisational biases are not as popular as technical improvements. However this is undoubtedly one of the most important directions to move towards in order to obtain more precise estimates. The third and last aim of this thesis is to address the methods proposed in literature to reduce or eliminate biases in estimates and propose a qualitative procedure to remove the causes of such biases. These two will be the topics of the sections that follow.

6.2 Methods proposed in literature for dealing with bias

As already said, in literature there are not many procedures proposed to tackle psychological and political-organisational bias in forecasting project cost and duration. The main sources are two studies conducted on relevant topics (Lovallo and Kahneman, 1992; Flyvbjerg and COWI, 2004). Starting from these two (especially the first), further studies have been developed, by the authors themselves and by others. However these two are the principal sources of methodologies that point at removing biases from estimates.

Both studies acknowledge the trend of project cost and duration underestimation. The first study focuses principally on psychological biases that lead to overoptimistic forecasts; once recognized these as the main causes of systematic errors, a formal way is proposed, which should help mitigating the psychological overoptimism. On the other hand, the second study focuses on political-organisational factors as the main source of biased estimates in public infrastructure projects; therefore this method is an estimate revision after forecasting process is completed. The two methods will be described below.

6.2.1 Reference-class forecasting

The study conducted by Lovallo and Kahneman has been already introduced. It is important to underline that both the authors developed many other researches on psychological aspects of elicitation, focusing on heuristics and common biases that influence people's way of thinking and taking decisions. Many of these studies are sources for psychological explanations discussed in chapter 4.
Hence it is possible to understand how the method proposed is aimed to reduce the psychological sources of biased estimates.

According to the authors, tendency towards optimism is unavoidable. In the same way, people tend to adopt the so-called 'inside view', as already mentioned in chapter 4, thus focusing tightly on the case at hand, considering objective, resources and obstacles. Therefore, to sum up what already explained about forecasting process and the authors' opinion, exploiting the implicit knowledge in forecasting is a double-edged sword. The positive contribution of adding value to forecasts is balanced by overoptimism.

The remedy proposed by Lovallo and Kahneman is the adoption of the 'outside view', also called reference-class forecasting. This approach should help obtaining more objective and reliable forecast by concentrating on comparing the current project to similar past projects. Talking about a research conducted on a group of experts which had to estimate the duration of a project, the authors state that:

> *"The outside view [...] completely ignored the details of the project at hand, and it involved no attempt at forecasting the events that would influence the project's future course. Instead, it examined the experiences of a class of similar projects, laid out a rough distribution of outcomes for this reference class, and then positioned the current project in that distribution"*

The result of this method was a more precise estimate, as the people involved were initially inclined to adopt the inside view and didn't think about comparing the project to a reference class.

Reference-class forecasting is a process organised into five steps:

- Select a reference class: identify a group of projects similar to the one considered. A good reference class is broad enough to be statistically meaningful but narrow enough to be comparable to the project at hand.

- Assess the distribution of outcomes: document the outcomes of the projects belonging to the reference class and arrange them as a distribution, showing extremes, median and any cluster.

- Make an intuitive prediction of the considered project's position in the distribution: based on personal intuition about the project at hand and how it compares to the reference class, a prediction of the outcome has to be made. This intuition will likely be biased.

- Assess the reliability of personal prediction: evaluate the confidence of the forecast made in the previous step, thus trying to estimate the correlation between forecast and actual outcome.

- Correct the intuitive estimate: it is necessary to correct the biased estimate made in the third step. Such estimate is adjusted towards the average, relying on confidence assessed in the previous step. The less confident is the estimate, the more it needs to be regressed toward the mean.

It is noted that this approach is generic and suitable for every kind of forecasts, whenever it would be possible to define a proper reference class. However this is not always possible; especially when project become larger and more complex, it is difficult to find similar past projects. In addition, for such projects, the outside view could represent a method to enhance forecasting process, which however cannot avoid cost and time estimating at activity level to reach a good level of accuracy.

6.2.2 Optimism bias up-lifts

Flyvbjerg started to address the problem of biased estimates considering both psychological and political-organisational explanations well accountable to describe the issue (Flyvbjerg, 1998). He then began to focus increasingly on political aspects, as his researches concerned mainly public infrastructure projects. In one of the last studies he proposed a method for dealing with optimism bias for British transport projects (Flyvbjerg and COWI, 2004). Once recognized the existence and the influence of bias in forecasts, Flyvbjerg proposes a method of estimates adjustment, taking a cue from Lovallo and Kahneman's study previously described.
The author first focused his effort on analysing different types of public infrastructure projects, collecting data concerning cost estimate at sanction gate (i.e. budget) and final actual cost. The proposal is then very simple: correcting

estimates with up-lifts based on trends of past projects belonging to the same category of the project at hand. Depending on the required level of certainty to stay in the budget and not exceed it, different values of up-lifts are provided for different percentiles. In table 6.1 the up-lift values are given.

Table 6.1

	Applicable optimism bias up-lifts				
Category	**50% percentile**	**60% percentile**	**70% percentile**	**80% percentile**	**90% percentile**
Roads	15%	24%	27%	32%	45%
Rail	40%	45%	51%	57%	68%
Fixed links	23%	26%	34%	55%	83%

The up-lifts indicated have to be applied to estimates at sanction gate. Flyvbjerg provides also a simple rule for estimate revision during execution phase, based on the percentage of total budget spent (Table 6.2).

Table 6.2

Percentage of total budget spent	**Up-lifts as percentage of initial up-lift**
0%	100%
25%	75%
50%	50%
75%	25%
100%	0%

It is important to point out that this study proposes a method focusing on British transport projects. There is a narrow focus on a considered sector and a considered country. These conditions make it possible to determine exact values for up-lifts that are realistic and supported by a wide research. Furthermore, in this kind of sector it is not difficult to compare similar projects developed in the same geographical reason. As a conclusion, up-lifts could be a valid answer to biased forecasts but it may be difficult to implement.

6.3 Improving awareness with post-project review

Improving forecasting precision has inevitably to do with qualitative advancement of forecasting process. If the most relevant sources of systematic errors are psychological aspects and political or organisational pressures, it is clear that it is necessary to act on the use of tacit knowledge and to correct the subjective approach to forecasts of practitioners involved.
There is a general tendency to overoptimistic estimation, as showed in chapter 2. Different projects, depending on political or organisational scenario, industrial sector or other boundary conditions, may have different sources of bias. However the common trend is an usual overoptimism in forecasting cost and duration outcomes.

The circumstances just described imply the need for a broadly revised approach to forecasts. Adjustments in such approach have to be done from a qualitative point of view. People involved in forecasting process and in project viability approval must always aim at steering towards the direction that ensures the highest benefits and profits for the organisations and for society. In this terms, practitioners' awareness about possible causes of flawed estimates is a key aspect that may help reaching an overall increased reliability. In the same two studies previously described, the authors agree on the necessity of awareness improvement. Lovallo and Kahneman first, then Flyvbjerg respectively suggest:

"Still optimism can, and should, be tempered. Simply understanding the sources of overoptimism can help planners challenge assumptions, bring in alternative perspectives, and in general take a balanced view of the future"

"The tendency toward optimism bias in infrastructure planning may be reduced through well structured institutional incentives and well designed processes for project documentation, appraisal and approval"

It is possible to improve awareness through a process of project revision, assessing the problems that occurred in forecasting cost and duration during the whole project life-cycle and trying to determine the causes.

6.3.1 The lessons learned problem

For long term perspective and general removal of causes of systematic errors, it is necessary to develop a formalised project learning process that could improve competencies and awareness. Such process cannot avoid documentation and meetings. The purpose should be harvesting the knowledge concerning 'know-how' and particularly 'know-why'. These conditions make debriefing a hard task, as it is necessary to assess implicit knowledge, which is difficult to document. Furthermore there is the tendency towards a lack of willingness to learn from mistakes and a scarce discipline in project debriefing that can lead to project amnesia (Schindler and Eppler, 2003). The main reason identified for such problems are:

- High completion pressure towards project end, concerning execution of late tasks and new activities waiting for the team members.

- Lack of communication relative to positive or negative experiences, due to 'wrong modesty' or fear of negative measures.

- Reluctance of team members to debrief closed experiences, as they could not see a personal advantage.

- Difficult coordination of debriefing procedures, as people involved in finished project are already engaged in new tasks.

The described difficulties cause a general reluctance to harvesting knowledge about the projects concluded and lack of improvement in awareness of the causes that can lead to biased forecasts.

6.3.2 A process for awareness improvement

In this section a process for post-project review is proposed, in order to increase awareness in practitioners involved in forecasting project cost and duration and approving project viability. Such process implies a meeting after project conclusion between project team members and all the above-mentioned people. The purpose of such meeting is to identify errors (if occurred) in cost and time estimates and assess the causes. In the end of the meeting, a document must be produced with all the errors and causes identified during the meeting.
This process is deliberately general and defined in broad terms, hence permitting the usage in every type of project and different organisation scenarios. This also permits the integration with an already developed debriefing process.

Proposed post-project review implies steps where participants perform quantitative and qualitative assessments, going over the whole project execution starting from sanction gate, focusing on differences between actual costs and durations and estimates approved. The following steps have to be implemented:

- Evaluate differences between cost and duration estimates and actual values. This assessment has to be performed for the entire project development, focusing on the discrepancies between approved baselines and real outcomes. The Earned Values trend described in chapter 1 represents the quantitative tool for this first step (Figure 6.3). The most important data are Final Cost Variation (FCV) and Final Duration Variation (FDV) (Table 6.3). These values are evaluated comparing final outcomes with budget and schedule approved at sanction gate. If such variations are higher than estimate accuracy, forecasts have suffered from unexpected or unconsidered problems.

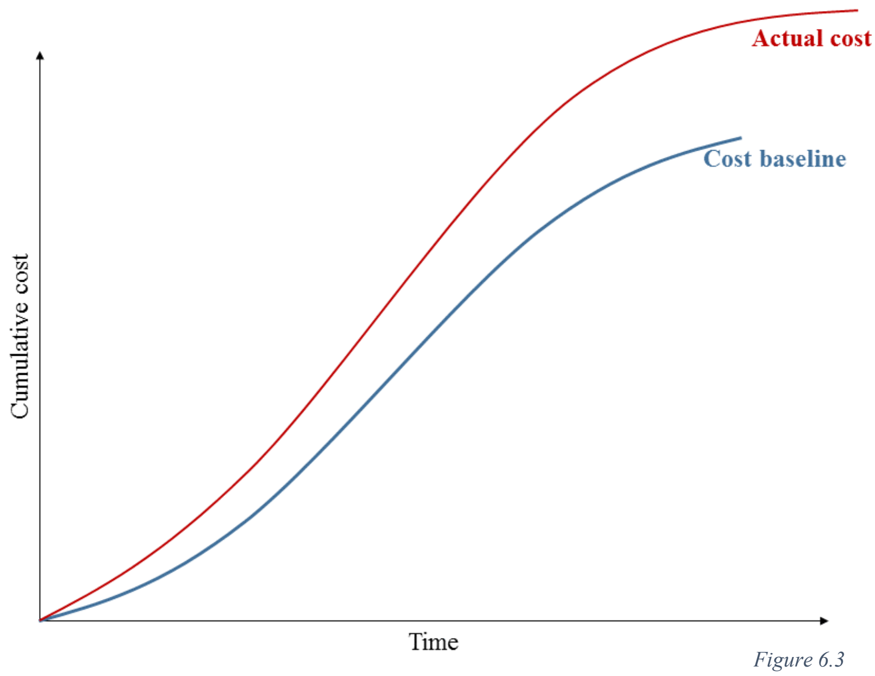

Figure 6.3

Table 6.3

Parameter	**Definition**	**Formula**
BAC	Budget at completion	
SD	Scheduled duration	
FC	Final cost (actual project cost)	
FD	Final duration (actual project duration)	
FCV	Final Cost Variation	$\frac{FC - BAC}{BAC}$
FDV	Final Duration Variation	$\frac{FD - SD}{SD}$

- Assess the causes for errors (unexpectedly high variations) considering all the possible explanations described in chapters 3, 4 and 5. If the project ended up with cost overruns and time delays, the sources of errors have to be sought mainly in psychological and political-organisational explanations. Once understood all the psychological biases and political or organisational pressures that can influence estimates, people have to assess which specific factors affected the forecasting process and, if noticed, which interactions or compensations acted between identified factors.

- Report variations and causes identified in the previous steps. Documentation is fundamental to guarantee that not only participants to meeting, but the whole organisations can benefit from awareness improvements.

- Brief practitioners, involved in early stages of similar project planning phase, on documented flaws of past projects. It is important to obtain awareness improvement in two ways. First, on people who participate to post-project meetings right after project conclusion; this will make them more conscious on possible influences in their future experience. Second, inform other people who can suffer from the same problems presented in past similar projects, making them conscious of how they can be influenced.

The described process is quite simple. The main difficulty is to win reluctances previously depicted. In case of projects that didn't present many problems and are characterized by low variations, this process may become a way to record best practices. Salient information about post-project meeting are collected in table 6.4. It is important to institutionalise this post-project review, organising the described meeting after every project completion and briefing teams on possible flaws. This leads to a continuous awareness improving process, both in practitioners and in the organisation's know-how.

Table 6.4

Post-project meeting

Participants	Project Manager, project team, practitioner involved in forecasting processes (both during planning and execution phase), practitioners involved in project viability approval at planning phase gates
Purpose	Identify FCV and FDV, address differences between cost and time baselines and actual developments, identify sources of errors and possible interactions
Provided documentation	Report FCV, FDV and other significant differences between cost and time estimates and actual values, report technical, psychological and political-organisational factors that influenced estimates

Chapter 7
Conclusions

In this thesis a general method to project review has been proposed. Such method is characterized by a process that aims at a primarily qualitative assessment of the causes of differences between cost and durations outcomes estimated during the whole project life-cycle and respective actual values. The efforts required for the application of this process aren't particularly great and a positive aspect is the possible integration with pre-existing debriefing processes. The purpose of the proposed post-project review process is to improve practitioners' awareness about the factors that could influence estimates calculation and approval, focusing especially on the causes of systematic errors.

The motivations that led to propose this post-project review method are the general documented trends of cost overruns and time delays in project management field. Such trends show a widespread tendency to cost and duration underestimation. The explanations mainly accountable for this type of errors are of a psychological and political-organisational nature. Consequently the factors that have a relevant influence on forecasting process are generally qualitative (egocentricity bias, for example, or organisational pressures). This importance of qualitative aspects bases the features of the proposed debriefing process.

Another important issue addressed by the post-project review method proposed in this thesis is the 'lessons learned problem'. Such method aims at harvesting, documenting and improving knowledge concerning 'know how' and especially 'know why', which is generally a difficult task in project management.

As a conclusion, the work conducted in this thesis puts forward a method that tries to tackle some of the most relevant critical issue to the project management scenario. In addition, this work could be considered an interesting contribution to the state of the art, as it offers:

- A review of broad studies that document a general trend of cost and duration underestimation in public and industrial projects.

- An overview of the explanations to the above-mentioned problem of systematic errors in forecasts.

- A brief description of the methods proposed in literature that strive for preventing or correcting biased estimates.

Besides the proposed method to post-project review, the work conducted in this thesis suggests that much more attention should be given to the problem of project cost and duration underestimation and the factors that can influence the latter. The importance of psychological and political-organisational aspects could be underrated when it comes to make forecasts about projects, especially when they represent a complex engineering challenge. Therefore, as well as debriefing practitioners after project conclusion on the causes of the errors occurred in forecasting process, it is important to implement an 'ex-ante awareness enhancement', in order to have people involved in future projects more conscious about the problems that may happen and the respective causes.

Finally, the work could be the basis for future developments both in academic and industrial field.
Interaction and relations between psychological biases can be the subject of a future study with a psychological narrow focus, trying to assess dependencies between different biases.
A research can be conducted interviewing project management practitioners about the sources and the relevance of systematic errors in forecasting project cost and duration.
A last development can be the application of the proposed post-project review method in a project-based organisation, in order to evaluate results and possible benefits.

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