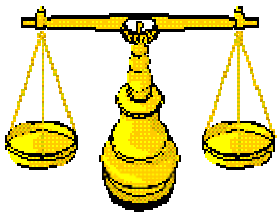
A Quantitative Approach to Software Releasing

Do the numbers really matter?

Concluding report - Orientation phase

June 25th, 2003



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1 Research Description

1.1 Introduction

This report describes the results of the *Orientation phase* of the thesis *A Quantitative Approach to Software Releasing*, conducted by the author of this document.

1.2 Outline

In the next chapters of this report, the following issues will be described:

- Chapter 2: Results from literature studies to build a control system for the case studies.
- Chapter 3: Case study questions addressed, derived from the initial central research question.
- Chapter 4: Results of the conducted case studies.
- Chapter 5: Conclusions with respect to the case study questions.
- Chapter 6: Overall conclusions and adjusted research questions.
- Chapter 7: Initial ideas with respect to a Conceptual Method as part of the *Design phase*.

In the *Glossary* a list of used definitions is given for important terms used in the remainder of this report.

1.3 Acknowledgements

The contributions of all the reviewers of this report as well as the previous concept edition are greatly appreciated.

Note: when the male form is used in this report, the female one is implied as well.

2 Software Product Development

2.1 Introduction

During the last decades the application of information technology (IT) in society has grown exponentially. Nearly every human being carries one or more computers with him. Examples are digital watches, mobile phones and credit cards. Further, nearly everybody uses other computers on a daily basis, both business-wise and for private purposes. Software can be found in televisions, vacuum cleaners, coffee machines, phones, board computers of trains and aeroplanes, medical equipment, and so on. There are some unique characteristics of software when comparing it to other material and immaterial goods. Messerschmitt et al. describe for instance [MES 2001, p. 4]:

> *"... On the supply side, its substantial economies of scale are much greater than material goods, with large creation cost but minuscule reproduction and distribution cost. ... On the demand side, software is similar to many material goods and to services in that its value in its behaviour and action it performs ..."*

It is also often commented what Niklaus Wirth, a former professor in computer science, once said:

> *"In programming, the devil hides in the detail."*

This is also a unique characteristic of software. The smallest defect during the implementation phase can have a tremendous impact.

The large application of IT has an enormous impact on society and as a result the software industry has become critical. Fact is that the development of IT products is often performed in an 'ad hoc' way. The Capability Maturity Model (CMM) as developed by the Software Engineering Institute (SEI) defines five different maturity levels for the development process of a software supplier [SEI 1995]. The SEI publishes twice a year a *Maturity Profile Update*. These profiles list the percentage of officially assessed[1] software suppliers performing at each level. At the end of 2002 the percentage of assessed suppliers still performing at the lowest maturity level equalled 24.8% [SEI 2002].[2] This indicates that the most important processes with respect to project management are not in place. It is commonly assumed, that the assessment of all software suppliers worldwide would show a far more dramatic picture. Some people estimate that 85% to 95% of all software suppliers are not meeting the criteria of CMM level 2.

This immaturity in the software engineering leads to an increasing number of accidents or even disasters. Leveson and Turner describe for instance an accident with medical equipment [LEV 1993]:

> *"Computers are increasingly being introduced into safety-critical systems and, as a consequence, have been involved in accidents. Some of the most widely cited software related accidents in safety-critical systems involved a computerized radiation therapy machine called the Therac-25. Between June 1985 and January 1987, six known accidents involved massive overdoses by the Therac-25 -- with resultant deaths and serious injuries. They have been described as the worst series of radiation accidents in the 35-year history of medical accelerators."*

Leveson has published a collection of well-researched accidents along with brief descriptions of industry-specific approaches to safety [LEV 1994]. Accidents are described in the fields of medical devices (the above mentioned Therac-25 accident), aerospace, the chemical industry and nuclear power. Other descriptions of accidents or disasters can be found for instance in [GLA 1998].

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[1] *'Officially' means here that the assessors have followed special courses organised by the SEI and that assessment results have been passed forward to the SEI.*

[2] *Currently, a transition takes place from the CMM to the CMMI ('I' stands for 'Integration'). The SEI has announced in early 2002 that support for the CMM will be stopped from 2004 on. Application results with the CMMI are scarce, caused by the fact that a limited number of suppliers have adopted the new model as a reference. Both models interpret 'immaturity' in the same way.*

The immaturity in the software engineering discipline surfaces when new software products are developed or existing products are maintained. Figure 2-1 shows different reasons for project failures, in 1998 roughly 28% of all software projects in the United States failed [STA 1998]. The cost of failed projects has been estimated at $85 billion for business in the United States in 1998 alone [BUS 1999].

The problems with regard to requirements and project planning potentially exist also for those projects that 'succeed'. These projects do release a product to their customers, but may be dealing with considerable budget overruns and schedule delays. Further, the released functionality and quality do not always correspond with the expectations of the clients.

The problems are caused by the fact that the development process of many software suppliers still resides at the lowest maturity level of the CMM. This does not imply that reaching higher maturity levels will automatically lead to the elimination of this fail factors. The only conclusion made here is that many software suppliers struggle with requirements and planning issues, because these are typical characteristics of a development process at the lowest maturity level.

	Failing factor	Percentage
1	Requirements are not explicit enough (different interpretations possible)	13.1 %
2	Requirements are unstable (they continuously change)	8.7 %
3	Project plans are incomplete and lack sufficient detail	8.1 %
4	Project plans are unrealistic (optimism often prevails)	9.9 %

Figure 2-1: Examples of failing factors in software projects [STA 1995].

The implicitness and dynamic nature of requirements (failing factors 1 and 2) as well as the incompleteness of project plans will often be the reason, that no clear release criteria for a software application will exist. Incomplete and unrealistic project plans (failing factors 3 and 4) will often lead to time pressure to release the software product prematurely. This is enforced by the fact, that many software suppliers have a short-term horizon disregarding the total life-cycle effects. In that case, the focus is on controlling the cost and schedule of the current product release. This potentially leads to sub optimisation instead of a strategic long-term approach.

The absence of clearly defined release criteria and the presence of time pressure to release as soon as possible imply that many software products are released without knowing the exact functionality and behaviour. Further, the absence of explicitly defined release criteria might be the origin of discussions between the customer and the supplier what had been agreed upon.[3] Disadvantages of a software product without the evaluation of predefined release criteria might be:

- *Unpredictable behaviour*. It is very difficult if not impossible to guarantee the customer what the exactly implemented functional and non-functional product needs of the software product will be. This may for example lead to a dissatisfied customer and to unforeseen, even potentially dangerous situations. Apart from the fact that people's lives may be at risk, such situations can have an enormous financial impact on the supplier.
- *Unknown operational costs*. The post-release or maintenance cost of the software products may be unexpectedly high. The exact status of the software product with its documentation is not known, which may cause high corrective maintenance cost. Further, extending the product with new functionality may be hampered (adaptive/perfective maintenance cost).

This leads to the formulation of the initial research question:

How to specify a method that can be used to determine the optimal economic moment to release a software product?

[3] *Issues that are not stated explicitly might be interpreted differently. The customer will interpret them as broad as possible to get as much out of his money. The supplier on the other hand will reduce them to save further cost.*

2.2 Research Themes

It is concluded here, that releasing a software product is a crucial decision as it can have a tremendous impact. Therefore, it would be preferable to have available defined and evaluated release criteria prior to the release decision. Expected advantages are:

- Chances on a project failure will potentially be reduced, because some potential failing factors (see Figure 2-1) are reduced or eliminated. The discrepancy between expectations of the customer and the supplier will probably be reduced as well.
- Having available the release criteria during the earlier stages of a project will probably lead to a more effective and efficient way of working: the project objective can be formulated more explicitly, steering the project team continuously into the right direction.
- The status of the software product and as a result the possible disadvantages for all stakeholders (like customer and supplier) can be better determined in quantitative or qualitative terms prior to the decision moment whether or not to release the software product.

Further, a release decision is also considered to be a complicated decision as in practice different stakeholders will be involved who will not all have the same preference with respect to the outcome. Further, the making of decisions in the real world is often unstructured [MAR 1979]. Therefore, it would be preferable to define software release decision-making as a process consisting of several functions. A process is defined here as *a set of instructions that defines a path to accomplish a predetermined objective*. A process-oriented approach is advantageous for many reasons [HAR 1987, p. 37], specific reasons in this context are:

- It indicates the dynamic nature of decision-making.
- It depicts decision-making activities as occurring over varying spans of time.

A decision is now defined as *a moment in an ongoing process of evaluating alternatives for meeting an objective, at which expectations about a particular course of action impel the decision-maker(s) to select that course of action most likely to result in attaining the objective.*

This leads to two central themes in this study, being *software product releasing* and *managerial decision-making*. These two themes are discussed in the next two sections, after which both themes are combined into one overall framework. Finally, some general considerations will be discussed with respect to software releasing.

2.3 Managerial Decision-making

In section 2.2 a process-oriented approach to decision-making was recommended. Harrision considers the decision-making process from a three-dimensional perspective, namely the individual functions of the process, the total process with interrelations and the dynamism of the total process [HAR 1987, p. 38].

2.3.1 Individual Functions

The functions of decision-making are [HAR 1987, pp. 38-39]:

- *Setting managerial objectives*. The decision-making process starts with the setting of objectives, and a given cycle within the process culminates upon reaching the objectives that gave rise to it. The next complete cycle begins with the setting of new objectives.
- *Searching for alternatives*. In the decision-making process, search involves scanning the internal and external environments of the organisation for information. Relevant information is formulated into alternatives that seem likely to fulfil the objectives.
- *Comparing and evaluating alternatives*. Alternatives represent various courses of action that singly or in combination may help attain the objectives. By formal and informal means alternatives are compared based on the certainty or uncertainty of cause-and-effect relationships and the preferences of the decision-maker(s) for various probabilistic outcomes.
- *The act of choice*. Choice is a moment in the ongoing process of decision-making when the decision-maker chooses a given course of action from among a set of alternatives.

- *Implementing the decision*. Implementation causes the chosen course of action to be carried out within the organisation. It is that moment in the total decision-making process when the choice is transformed from an abstraction into an operational reality.
- *Follow-up and control*. This function is intended to ensure that the implemented decision results in an outcome that is in keeping with the objectives that gave rise to the total cycle of functions within the decision-making process.

2.3.2 Total Process with Interrelations

Figure 2-2 shows both the interrelations between the six individual functions [HAR 1987, p. 40]:

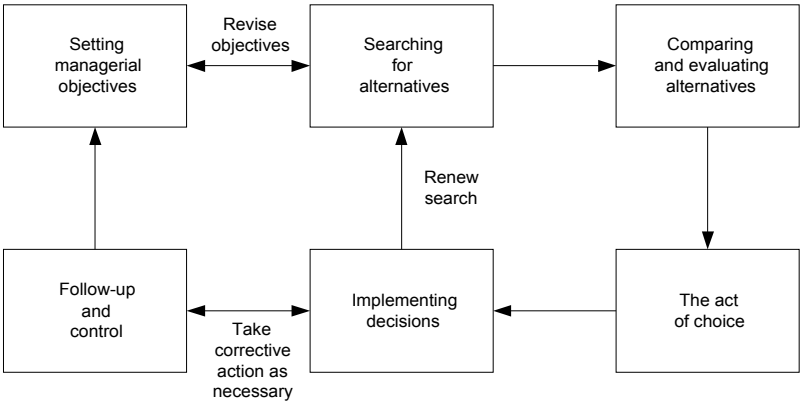

Figure 2-2: The decision-making process [HAR 1987, p. 40].

The process starts with the setting of objectives, which requires the search for information or alternatives. Alternatives are compared and evaluated, where after the selected alternative is implemented. Follow-up and control of the implemented decision reveal to management the actual outcome of the decision.

2.3.3 Dynamics of the Total Process

The dynamics of the total process consist of three principal sub processes among the different functions [HAR 1987, p. 41]:

- *Corrective action*. This sub process is activated when it becomes apparent to management that the implemented decisions do not meet the set objectives.
- *Search renewal*. When the corrective action is not working or too costly to continue, the search may be renewed to (re-) consider other alternatives.
- *Objectives revision*. When both the corrective action and the search renewal have failed, management will have to revise the objectives.

2.4 Software Product Releasing

2.4.1 First Orientation

Few references have been found in literature, elaborating solely on the subject of releasing (software) products. The most promising titles found were *Software Release Methodology* [BAY 1999] and *Real options and competitive dynamics in software product release* [COT 2000]. The first one is however a technical-oriented book about source code control, testing and defect tracking and release engineering. The second reference focuses in abstract terms on investments with a high level of uncertainty.

Regarding the determination of the 'right' moment to release a software product, many research studies have focused on reaching an 'acceptable' level of reliability, or in other words: *When to stop testing?* In

practice, often a combination of the following non-analytical methods is used to decide when a software product is 'good enough' to release [RTI 2002]:

- A 'sufficient' percentage of test cases run successfully.
- Statistics are gathered about what code has been exercised during the execution of a test suite.
- Defects are classified and numbers and trends are analysed.
- Real users conduct beta testing and report problems that are analysed.
- Developers analyse the number of reported problems in a certain period of time. When the number stabilizes or remains below a certain threshold, the software is considered 'good enough'.

From the late seventies onwards, there have also been initiatives to define software quality models, which address more product attributes than reliability only. Research and publications of for instance McCall [McC 1977] and Boehm [BOE 1978] have led to the ISO/IEC 9126 standard [ISO 1991]. This standard distinguishes six different classes of product attributes.[4] See Figure 2-3. Regarding the release process itself, there is one standard available being the ISO/IEC 14598 standard [ISO 1999]. It is of an abstract nature and provides only limited practical guidelines to support the release decision-making process.

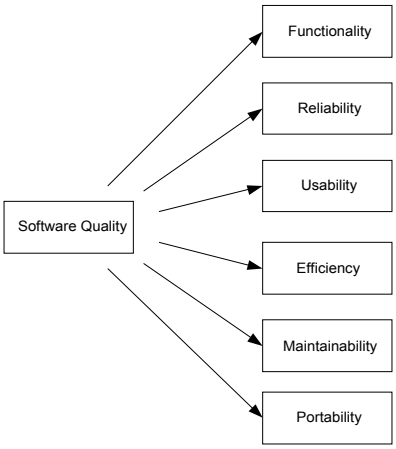

Figure 2-3: Classes of product attributes describing software quality [ISO 1991].

2.4.2 Controlling Software Projects

Due to the limited availability of relevant references in literature, another approach was taken towards the orientation on the theme of software releasing by studying literature regarding the control of software development projects.

De Leeuw described a general approach to the effective control of a target system [LEE 1994]. He represents a control situation by a controlling organ, a target system and an environment (see Figure 2-4). The controlling organ exerts goal-directed influence on a target system, while the environment affects both the controlling organ and the target system.

[4] *In this study the primary interest is in the product attributes or non-functional product needs 'reliability' and 'maintainability', as they determine to a high degree the operational cost after having released a product. Definitions used are based on [IEE 1990] and can be found in the Glossary.*

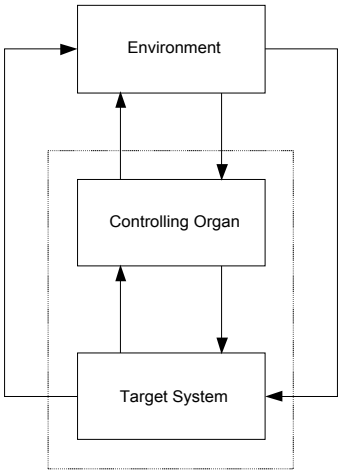

Figure 2-4: Simple control system [LEE 1994].

The systems theory of control states five requirements for effective control, as depicted in Figure 2-5 [LEE 1990].

	Requirement	Description
1	Goal	The controlling organ should specify goals for the target system, which may or may not be constant in time or stated explicitly.
2	Model	The controlling organ should have a model to predict the possible effects of the control measures, or should at least have a good understanding of the target system.
3	Information	The controlling organ should have sufficient information about the state of the system and the environmental influences, and embrace the means for acquiring und updating this information.
4	Measures	The controlling organ should have enough measures of control at its disposal or the organ must encompass enough degrees of freedom to cope with possible environmental and system disturbances.
5	Capacity	The controlling organ should have sufficient data handling capacity, which enables the use of the information required for taking control meaures.

Figure 2-5: Requirements for effective control [LEE 1990].

Hollander adapted the control system of Figure 2-4 to the controlling power of business development teams [HOL 2002, p. 52] in the following way:

- The *environment* is based on Porter's five forces model, being the company and its competitors, the customers or buyers of the product, the suppliers, the substitutes for the product and new potential entrants from other markets [POR 1980, p. 4].
- The *controlling system* consists of the project management function.
- The *target system* is the business development project.

This general description of a control system can in the same way be adapted to software development projects. The argument used is that a software development project can be regarded to as a business development project. Also the five requirements for effective control can be adapted. Argument here is that these requirements for effective control are found back in many project management approaches that have been developed to control software development projects. Examples are:

- *System Development Methodology (SDM)*. SDM distinguishes seven phases and prescribes the activities and resulting products or deliverables for all phases [TUR 1990]. In each phase attention is given to four aspects being: system development, validation, control and organisational change.
- *PRINCE2*. In order to describe what a project should do when, PRINCE2 has a series of processes which cover all the activities needed on a project from starting up to closing down [CCT 2002]:
  - An organised and controlled start by organising and planning the project properly;
  - An organised and controlled middle when the project has started to make sure it continues to be organised and controlled;
  - An organised and controlled end consisting of a formal project closure and evaluation.

The adapted control system of De Leeuw is presented in Figure 2-6. Specific interpretations made are:

- *Environment*. The environment is still based on Porter's five forces model conform the ideas of Hollander. Senior Management performs the analysis of the environment and documents the results in a business strategy.
- *Controlling Organ*. The controlling organ is the Project Steering Committee, which is responsible for the project management function. In the project management approaches like SDM and PRINCE2, one of the first responsibilities assigned to this committee is making a cost/benefit calculation. In SDM a high-level calculation is made in the first phase and a detailed calculation in the second phase. PRINCE2 prescribes the definition of a business case at the start of a project, describing expected benefits and cost, as well as periodic updates of the business case during the project execution. This is an economic approach to software product development.
- *Target System*. The target system is the Software Development Team, responsible for planning and executing the project. The team activities are derived from the business case and further detailed in a project plan.

This interpretation leads to a control situation as depicted in Figure 2-6.

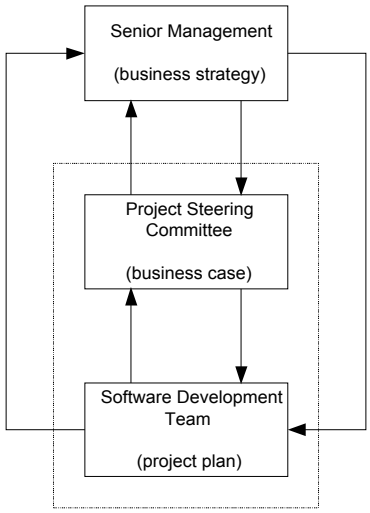

Figure 2-6: Control situation for software development projects.

An aspect to bring forward here is the following. Many studies have taken place to investigate the factors that determine the success or failure of product development. Hollander gives an overview of many different studies with a strong focus on new product innovations in commercial marketplaces, in other words new business development projects [HOL 2002]. Hollander made an analysis of this large number of success and failure studies and defined four constructs for business development projects with related factors [HOL 2002, p. 45]. See Figure 2-7.

Constructs	Factors
Company	Strategy Project-Company Fit Project Resources
Team	Communication Project Leader Project Team
Product	Product Superiority Product Scope Product Aspects
Market	Market Competition Market Volume Environment

Figure 2-7: Constructs and factors for assessing business development projects.

These constructs can be mapped on the derived control system for software development projects. The company- and market constructs address long-term aspects and are reflected in the overall business strategy, the product constructs are reflected in the business case and the team constructs are to be taken into account in the project plan. See Figure 2-8.

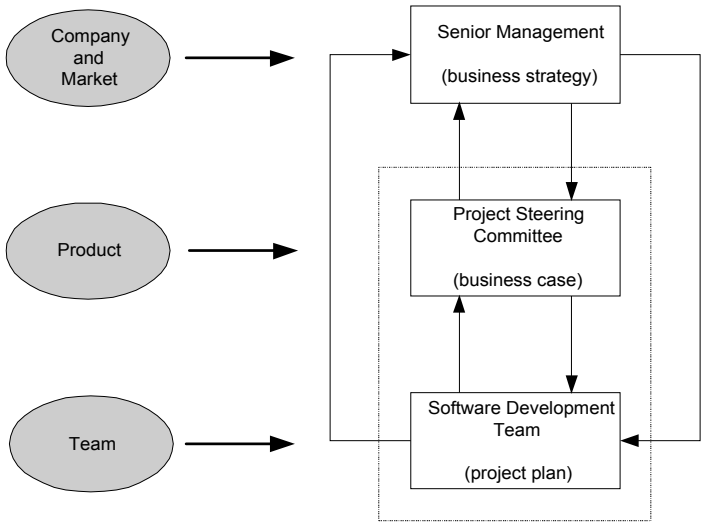

Figure 2-8: Relationship between constructs and control system.

2.4.3 Product Development Steps

The derived control system for software development projects, the five requirements for effective control and the defined constructs are all ingredients that contribute to the success of product development. In this section it will be described in general how a software development project could be started and further executed till the rollout of the resulting product. The release decision is made when the product is transferred from the development phase to the operational phase. Special attention will be given to the area of release criteria.

Senior Management at a strategic level defines a *business strategy*, describing the long-term expectations with respect to business and technology developments. Business developments are addressed in terms of changes in the marketplace and organisation. Technology developments are addressed in terms of adoption of new technologies and new application of existing technologies. The business strategy is the input for Product Management (or the department responsible for information planning) at a tactical level to derive *business cases*. It is assumed here, that in general the definition of a business case and its further implementation at operational level afterwards are executed in different development steps. They will be further explained.

Investment proposal
A business case is used to define the rationale for a project that is initiated to develop a product (either a new product or a newer version of an existing product) [REI 2002]. It is in fact a proposal to start investing in a project definition. It describes the expected revenue for the supplier organisation taking into account the expected development or pre-release cost (to develop the product) and operational or post-release cost (to produce, deploy and maintain the product). The business case defines in high-level terms the *external product needs and constraints* as input to a project at operational level. The external product needs describe the required functionality seen from the perspective of the customer(s). Distinction can be made into functional needs and non-functional needs. The functional needs describe the functionality that must be offered by the product. The non-functional needs define product properties and put the constraints upon the functional needs. They determine the behaviour of a product. Examples are: reliability, safety and accuracy. There are often referred to as quality attributes. In the non-functional needs, the compliance to external standards is included in addition. Constraints determine the boundaries of a project and may, for instance, be limitations with respect to budget and lead-time of the project and cost price of the final product.

Project definition
Internal stakeholders define *internal product needs and constraints*. The internal product needs are also expressed in functional and non-functional needs. Functional needs describe for instance the documentation that is needed to produce, deploy and maintain the resulting product. Non-functional product needs describe for instance the compliance to internal standards. The combination of the *external product needs and constraints* and the *internal product needs and constraints* are the inputs to the project. They are further analysed and detailed to the level where one or more project alternatives can be defined, that meet the formulated needs and constraints. The project alternative that most satisfies them will be selected. At this stage, the release criteria can be defined. They are *the particular criteria of a project and its resulting products that are taken into account to make the decision whether or not to release the product*.

Product design
After the project has been defined and accepted, the project starts. Further analysis of all needs and constraints will lead to the formulation of different product design alternatives. The design alternative that most satisfies the release criteria will be selected. After the product design has been selected the release criteria are deployed to lower-level process and product attributes. Suppose that lead-time and budget are constraints and thus release criteria. They will put constraints on each component as defined in the product design. If for example, reliability and maintainability are part of the non-functional needs, they will have to be deployed in some way to the defined components in the product design. It may not always be possible to conduct a simple mathematical breakdown of a non-functional need. In that case implementation rules may be defined that will implicitly contribute in meeting the non-functional need at product level. Parnas for instance described how a high level of extension or maintainability could be obtained through design rules [PAR 1997].

During further implementation of the product the project must stay aligned with the business case. The status of the project is obtained by evaluating the defined and deployed release criteria. Currently measured values and predictions of final values form the *pre-release data*. A steering committee may be in place to discuss the *pre-release data*, combined with any new insights. For instance, the business case may have been changed due to market developments or the service department may come up with additional product needs.

Product release
The continuous alignment of the status of the project with the status of the *external product needs and constraints* and the *internal product needs and constraints* will finally lead to a situation where the release decision can be made. Release alternatives to be considered are:

- Release now.
- Release later after the successful implementation of some corrective actions.
- Do not release the product and stop the project.

Investment and project evaluation
After the product has been released, assuming that the project is not stopped, data is needed to determine the result of the business case. A distinction is made between *end-user data* (for instance the revenues of the product and the customer satisfaction) and *post-release data* (for instance the cost of corrective maintenance). Evaluation of these data might result in changes to the *business strategy* and future business cases, as well as removal of organisational process deficiencies (root-cause analysis).

Using this model, the success of a release decision can be described as (based on [TRU 1966]):

$$\text{decision success} = f(\text{criteria definition}) + f(\text{criteria deployment}) + f(\text{criteria evaluation}) + f(\text{decision quality}) + f(\text{decision implementation}) + f(\text{decision evaluation})$$

Based on the description of the different product development steps, the derived controlling situation for software development projects (see Figure 2-6) can be defined more detailed. Further, with respect to software releasing an improvement will be to make a distinction between the development of the product and the release of the product and the evaluation of the released product. These refinements are shown in Figure 2-9.

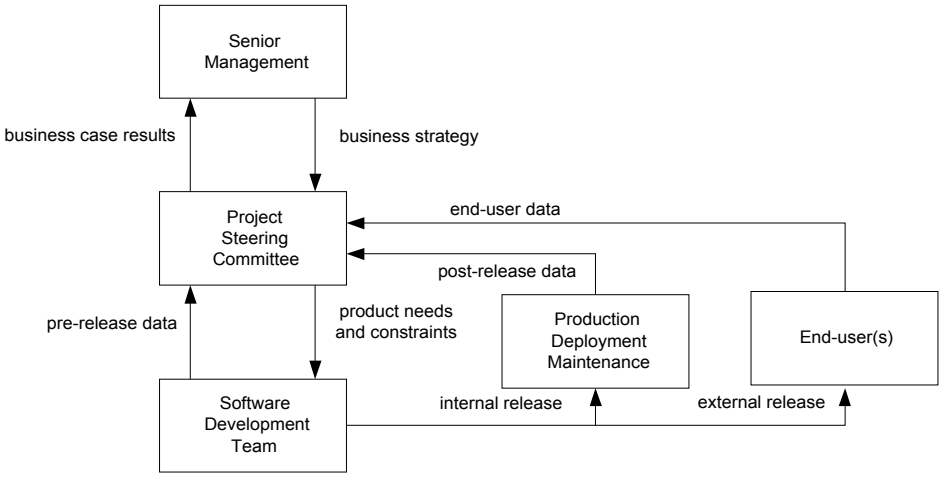

Figure 2-9: Refined control system for software product development.

2.5 Decision-making and Software Product Releasing

How do the product development steps as described in the section 2.3 correspond to general decision-making process as described in the section 2.2? The mapping is (see also Figure 2-10):

- The function *Setting managerial objectives* in the sense of software product development is in fact defining the high-level business case as an investment proposal.
- The next four functions *Searching for alternatives -> Comparing and evaluating alternatives -> The act of choice -> Implementing decisions* are in fact repeated three times: when defining the project, when selecting the product design and when making the product release decision. Note here, that the process of interrelations and the dynamics of the total process are still valid.
- The function *Follow-up and control* in the sense of software product development is in fact defining the evaluation of the made investment made and the executed project.

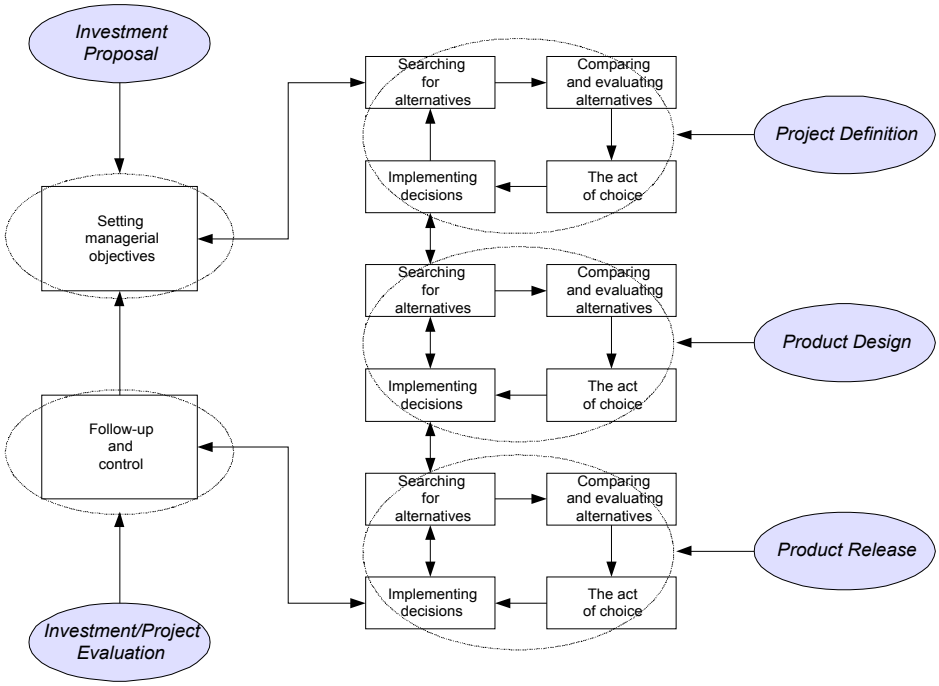

Figure 2-10: Relationship between decision-making process and product development steps.[5]

[5] *In order to reduce the complexity of this figure, not all possible subprocesses have been depicted. Further, no attention has been given to the fact that during Setting Managerial Objectives and The act of choice (three times) one has the possibility to stop product development.*

The previous elaborations and presented control system may be easily recognised by industrial companies, developing commercial products for external customers (business-to-business or business-to-consumer). A valid question here is whether the raised issues can also be applied in those organisations, where IT investments are not directly initiated for commercial purposes. Other reasons to invest may for instance be: replacement investment, productivity investment, infrastructure investment and a mandatory investment [BUT 1990].[6] In these cases the presented control system may not be fully applicable. Examples of deviations may be:

- There are no external end-users, but internal end-users.
- The level of competition is different (in fact, there might be no competitors at all).
- It will be harder to express a business case in financial terms (different investment types).
- The introduction of the product might affect the organisational processes within the own organisation.

On the other hand, the main principles stay the same. Ideally, product management or the IT-department is directed by a long-term strategy (the business strategy) and there must be a business case as the rationale for at least each strategic project with a high investment level. A release decision is to be made based on the evaluated release criteria and after the product has been released externally and internally, the result of the business case can be determined in quantitative or qualitative terms.

2.6 Release Considerations

2.6.1 When to Release?

One could state that the one and only appropriate measure a commercial software supplier would place on the decision whether or not to release a product is the profit difference. Suppose a software supplier produces a product to be sold at a price ***p***. Profits are revenues (price times quantity) minus cost (pre-release and post-release cost):[7]

supplier profits = revenues – cost = p . q – pre-release cost – post-release cost

In order to be able to predict profits the following sub questions related to expected revenues and cost must be answered (see also Figure 2-11):

- Which product needs have been implemented and tested?
- What are the current levels of reliability and maintainability compared to their targeted values?
- What are estimated sales figures (price, quantity, reputation) when the product is released now?
- What are estimated post-release or operational cost when the product is released now, taking into account both corrective maintenance and adaptive/ maintenance activities?

As a second step the other situation must be considered. Delaying the time to market will have several consequences depending on the phase in the product's lifetime and the characteristics of a market as discussed before. Extending the lead-time may bring extra functional product needs, higher levels of reliability and maintainability, that may have a positive effect on price and quantity, but the impact may be negative as well in a highly competitive market.

supplier profits` = p` . q` – pre-release cost` – post-release cost`

In order to be able to predict profits in the counterfactual situation the following sub-questions related to expected revenues and cost must be answered:

- What are the additional pre-release or development cost to improve and extend functional product needs?

[6] *In practice it will be difficult to classify an investment in software product development uniquely. The resulting product may contain many aspects [BER 1997, p. 78].*

[7] *In this simplified model other cost, like production cost and sales cost, and discounted value calculations are not taken into account. Further, the post-release cost will in practice probably depend on the number of products sold.*

- What are the additional pre-release or development cost to improve the reliability and maintainability?
- What will be the impact on sales (price, quantity, reputation) when market introduction is delayed?
- What will be the impact on post-release or operational cost when the reliability and maintainability are improved?

Ideally, when it would be possible to measure all information needed, the profit difference of the supplier could be calculated as:

delta (supplier profits) = supplier profits – supplier profits`

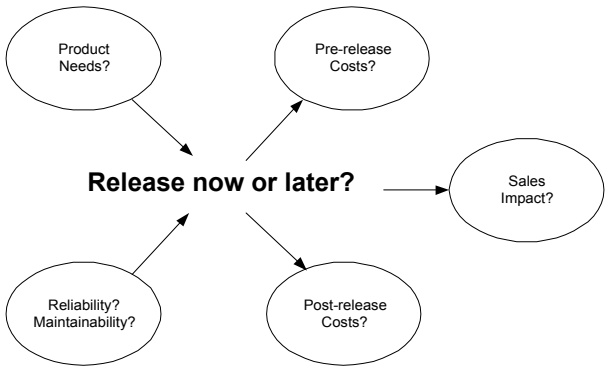

Figure 2-11: Product releasing: commercial products.

2.6.2 Priorities

When developing products, not all release criteria will be equally important for a project. Moore investigated why many new technology companies started with new inventions and rapid market growth, but to collapse within the next three years [MOO 1995].[8] He explained the phenomenon by recalling an earlier model of mindsets towards the adoption of technologies (this will later also be discussed in section 7.4.2). Initial success is gained by selling products to technology enthusiasts and visionaries, who are quick to grasp the implications and care less about for instance reliability. However, when the market of visionaries becomes saturated, the attempt to sell the technology to pragmatists might fail as they care more about stability or reliability. Moore used the metaphor of a chasm: the company leadership discovers too late that it does not communicate with the pragmatists. See Figure 2-13. Moore also presented a model, showing how the project priorities or criteria shift during the evolvement of a product [MOO 1995]. See Figure 2-12.

Market description	Introduction	Early Adopters	Mainstream	Late Majority	End of Life
Buyer profile	Technology enthusiasts	Visionaries	Pragmatists	Conservatives	Skeptics
Importance	1. Time to market 2. Product Needs 3. Reliability	1. Time to market 2. Product Needs 3. Reliability	1. Reliability 2. Time to market 3. Product Needs	1. Reliability 2. Product Needs 3. Time to market	1. Reliability 2. Product Needs 3. Time to market

Figure 2-13: Project priorities as a function of a product's lifecycle [MOO 1995].

[8] *See for instance also [DEN 2001] in which the results of Moore's study are summarized.*

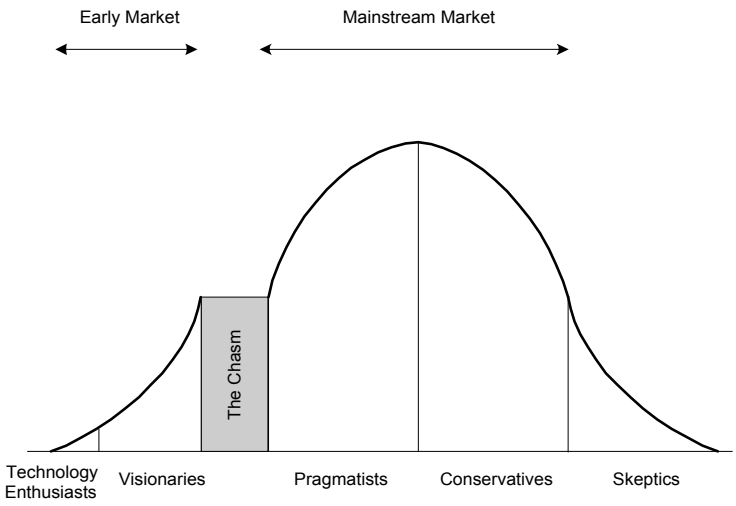

Figure 2-13: Chasm between the early market and the mainstream market [MOO 1995].

2.6.3 Cost and Time to Market versus Quality

Developing software products is normally characterized by business pressure to minimize cost and time to market. It is often stated that delivering a higher quality product does not necessarily mean that development cost will increase. This is only partially true. For instance, striving for higher reliability and maintainability through investing in appraisal techniques like reviews and inspections will be paid back by a decrease in the repair cost of finding and fixing defects ([ROI 1996], [SAS 2002]). There is however an optimal level (see Figure 2-14). Beyond this point a further increase in appraisal cost will not have a net positive effect (for sake of completeness, the effects on post-release cost should also be taken into account):

delta (appraisal cost) + delta (repair cost) < 0

Whether a further increase in appraisal needs is justified or not will depend on the specific circumstances, for example market characteristics. In some cases, reliability has such a high priority that an organisation can hardly afford to deliver below a certain level.

Time to market is also influenced by the phase in the product's lifetime as well as other characteristics of a market, for example the level of competition. Figure 2-12 depicts the release priorities of a software product as they evolve through a product's lifetime. Figure 2-15 depicts some examples of profit models related to time to market. When, for instance, the entry of a new product is delayed in a market with heavy competition, the probability of a supplier capturing the advantages of *Early Adopters* will decrease.

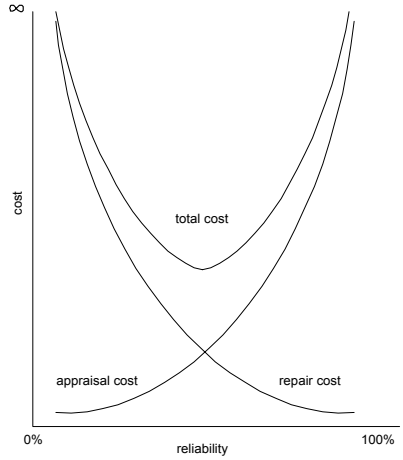

Figure 2-14: Appraisal cost versus repair cost [SAS 2002, p. 18].

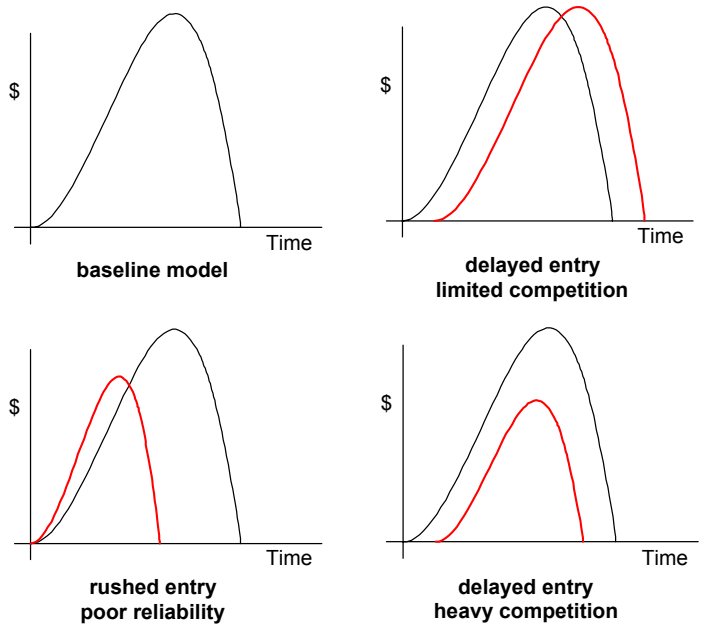

Figure 2-15: Examples of profit models [SAW 1999, p. 13].

3 Case Study Questions

3.1 Introduction

In section 2.2, the initial research question was formulated as:

How to specify a method that can be used to determine the optimal economic moment to release a software product?

The formulated research question was based on the following assumptions:

- *Assumption 1*. The objective of a release decision is to maximize the resulting economic value.[9]
- *Assumption 2*. The economic value can be calculated, in other words the variables that determine the economic value can be expressed in financial, quantitative terms.
- *Assumption 3*. If the objectives of the release decision have been predetermined in a managerial decision-making process, the criteria used must be available prior to the release decision in order to steer product development into the right direction. They must support the selection of different alternatives during the different stages of product development, after project definition.

The studies presented in this report are used to verify these assumptions, in other words whether the central research question is a valid one or not. However, the studies also have an exploratory character. This means that data not contributing directly in verifying the assumptions, but considered important for the next phases of this thesis, will also be collected. In the next section, questions are derived that will be specifically used to verify the assumptions.

3.2 Questions

Assumption 1 in the research question is that the objective of a release decision is to maximize the economic value. This corresponds to the idea that the decision-making process can be described with the Rational Model of Harrison [HAR 1987, pp. 150-153]. Two specific questions are raised here to verify this assumption. How can the release decision be characterized and which decision-making model applies to a release decision?

1.a How can the release decision be characterized?

Harrison describes a categorization of decision characteristics [HAR 1987, p. 21] and distinguishes:

- ***Category I decisions***. This category includes the routine, recurring decisions that are handled with a high degree of certainty.
- ***Category II decisions***. This category includes the nonroutine, nonrecurring decisions that are handled with a high degree of uncertainty.

The decision category determines at which level in an organisation a decision is to be made. Higher management must concentrate on nonroutine decisions (Category II), routine decisions must be left to operating management (Category I).

In the case studies the following issues will be studied:

- *How can the release decision be characterized with respect to routines, recurrence and certainty of the outcome?*

[9] *It is not assumed here that the Law of diminishing returns automatically applies. Although this fundamental law, describing a major economic principle, might be true in many cases, there are examples found nowadays that do not comply to (the common sense of) this law. The production and commercialisation of software products is not only based upon physical labour and capital. Instead, there is a shift towards the production and commercialisation of software products based upon information and knowledge. This shift leads to situations where one should think in terms of increasing returns: adding more information and knowledge can lead to an increase in output of products, which is more than proportional. Large initial investments are made during the research phase, the cost to produce are small. See also [HAR 2001].*

- *Is this characterization influenced by factors like the type of application or the strategic importance of the product?*

1.b Can the decision to release a product be described with one of the four decision-making models of Harrison [HAR 1987]?

Harrison describes a typology of four decision-making models [HAR 1987, p. 152 and pp. 170-171]:

- The ***Rational Model*** (classical, primary criterion: maximized outcome). This is a normative model and has its foundation in quantitative disciplines like economics and mathematics. The model is based on the assumption that all the significant variables in decision-making process can be quantified to some degree. As the model operates within an artificially closed environment, it applies mainly to Category I decisions.
- The ***Organisational Model*** (neoclassical, primary criterion: satisfying[10] outcome). This model combines the behavioural disciplines (like philosophy, psychology and sociology) with quantitative analysis to make a decision that fits the constraints caused by the external environment. It is suited for Category I and Category II decisions.
- The ***Political Model*** (adaptive, primary criterion: acceptable outcome). This model is almost totally behavioural and the primary criterion for decision-making is the outcome that is acceptable to many external constituencies (bargaining, compromises). It has a de-emphasis on objectives-oriented outcomes.
- The ***Process Model*** (managerial, primary criterion: objectives-oriented outcome). This model is oriented toward innovation and organisational change with a particular emphasis on long-term results. It is well suited for Category II decisions.

The models differ from each other with respect to the primary decision-making criterion and some key assumptions.

In the case studies the following issues will be studied with respect to making the final release decision:

- *What is the nature of the objective(s) of the decision (fixed, attainable, limited or highly dynamic)?*
- *Which information is available to make the decision? Is it limited or unlimited?*
- *Are there cognitive limitations?*
- *Are there cost and time constraints?*
- *To which extent are the release criteria quantifiable?*
- *Is the environment open or closed?*
- *Is the outcome limited in qualitative and quantitative terms?*

Assumption 2 states that the economic value can be calculated, in other words the variables that determine the economic value can be expressed in financial, quantitative terms. One question is raised here to verify this assumption. To which extent can the outcome be expressed in financial terms?

2. Can the outcome of the release decision be expressed in financial terms?

According to the definitions used, a project is defined by making a trade-off between desired product needs and stated project constraints, resulting in a defined project with defined product needs and defined project constraints. This process is in fact repeated during the design phase of the project when selecting the product design that fulfils the project definition. In the product design components are identified and ideally, the release criteria at project level can be deployed to sub criteria at component level. In this way, the scope of work is clearly defined at component level. Further, evaluating the release criteria can then be performed by evaluation of the sub criteria at component level and calculating the resulting values at product level. This process will probably hold for certain release criteria, like for instance lead-time and budget. However, for release criteria like reliability and maintainability (as part of the non-functional requirements, using for instance [ISO 1991] as a reference) the situation might be different. Quality models like [ISO 1991], [BOE 1978] and [McC 1977] provide little guidance to determine how tangible lowest level metrics at component level can be used to evaluate non-functional requirements at product level. Dromey suggests instead a bottom-up approach by defining and building in a consistent, harmonious, complete set of product properties and linking these product properties to the high-level

[10] *Harrison uses the term 'satisficing', however this word was not found in any dictionary and has been replaced by 'satisfying'.*

non-functional requirements [DRO 1996]. He distinguishes the following categories of product property classifications carrying quality:

- Correctness properties.
- Internal properties.
- Contextual properties.
- Descriptive properties.

He identifies two categories of implementation components: those that describe computations and those that describe data. An empirical process is used to determine the quality-carrying properties for each implementation component and their relationship to the property classification(s). An example is given in Figure 3-1.

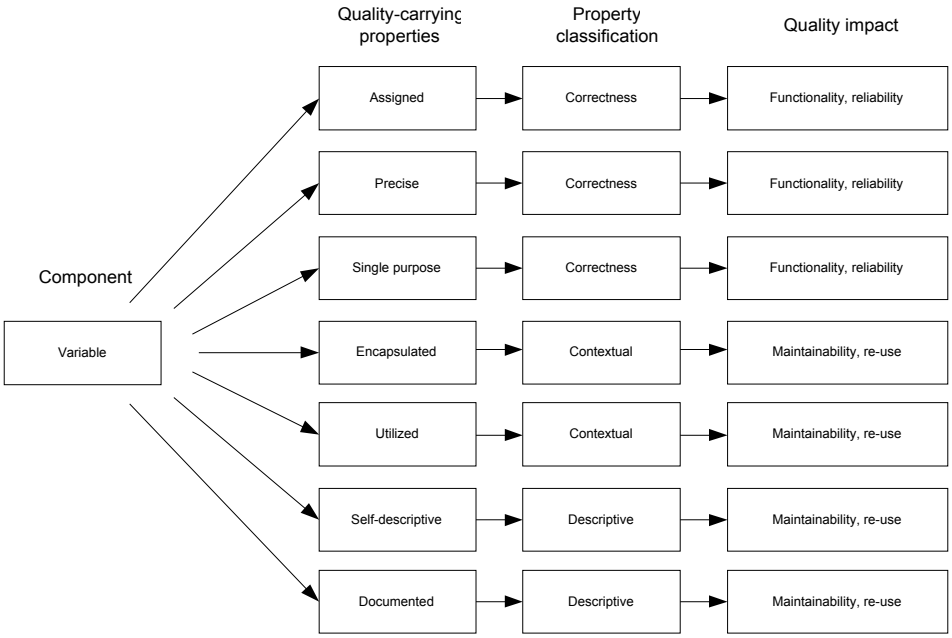

Figure: 3-1: Product properties of a variable component and their effect on quality [DRO 1996, p. 37].

In the case studies the following issues will be studied:

- *Are the release criteria at project level deployed to the identified components in the selected design?*
- *How are the values of release criteria evaluated?*
- *To which extent can the release criteria be completely and reliably evaluated?*
- *To which extent can the evaluated release criteria be expressed in financial terms?*

Assumption 3 in the research question states that the prioritised criteria used must be available prior to the release decision in order to steer product development into the right direction. One specific question is raised here to verify this assumption: Can release criteria and their priorities be used to select amongst different alternatives?

3. Can prioritised release criteria be used to select alternatives?

Grady describes three possible strategic project goals of software suppliers [GRA 1992, p. 22]:

- Maximize customer satisfaction. This is accomplished mainly by offering products, which will both satisfy and delight customers. Other factors are important as well, for instance the price of the product and the required level service and maintenance efforts and cost from a customer's point of view. Maximizing customer satisfaction means for a project that essential ***product needs*** must be identified and implemented.
- Minimize engineering effort and schedule. Improving productivity is important, as it will help to decrease development cost (from which a customer may also benefit). Shortening development times will help to deliver products faster, which can be a highly competitive advantage in today's marketplace (and can offer another benefit to a customer). Minimizing engineering effort and schedule means for a project that work must be performed efficiently to reduce cost and that ***time to market*** must be minimized.

- Minimize defects. Minimizing defects during development will limit the amount of rework. This will also have a positive impact on minimizing engineering effort and schedule. Further, post-release cost will probably decrease as the product contains fewer defects. The customer will also benefit from reliable products and thus minimizing defects will have a positive contribution to customer satisfaction. Minimizing defects means for a project that product must be developed with a high ***reliability***, which can be accomplished for instance by applying appraisal methods like reviews and inspections.

When developing products not all goals will be equally important for a project. Moore states that it depends on the lifetime of a product, which goal has highest importance, see Figure 2-12 [MOO 1995]. The priorities of the goals shift during the evolvement of a product. According to the used definition of release criteria (see Glossary) project goals like time to market or lead-time, product needs and reliability as a non-functional product need are release criteria.

In the case studies the following issues will be studied:

- *What are the priorities of the release criteria in the current project?*
- *Do they correspond to the model of Moore?*
- *What are the criteria and their priorities used to select (search for, compare and evaluate) different alternatives?*
- *To which extent do these selection criteria correspond to the release criteria?*

3.3 Research Strategy

Several research strategies were considered to obtain answers to the questions raised. The questions are a combination of *hows*, *whats, why's* and so on due to the exploratory character in this phase of the research project. As no control is required over behavioural events and the focus is on a contemporary event[11], it was decided to use exploratory case studies as the main research strategy, combined with two surveys and an archival analysis by studying documentation. The choice for this combined strategy is based on [YIN, pp. 4-9]. See Figure 3-2.

Further, three principles were considered important when collecting data [YIN 1994, pp. 90-99]:

1. *Use multiple sources of evidence*. It was decided to interview people, to use surveys and to study available documentation. Further, available documentation as well as the results of one survey were studied before the interviews took place in order to cope with the effects of bounded rationality when people were interviewed.
2. *Create a case study database*. It was decided to make an explicit distinction between on one hand the data obtained through interviews, surveys and documentation and on the other hand the resulting case report.
3. *Maintain a chain of evidence*. In this report, the external observer or reader can follow the derivation of any conclusions from the initial research question as formulated in section 2.2.

Research strategy	form of research question	requires control over behavioral events?	focuses on contemporary events?
Experiment	how, why	yes	yes
Survey	who, what, where, how many, how much	no	yes
Archival analysis	who, what, where, how many, how much	no	yes / no
History	how, why	no	no
Case study	how, why	no	yes

Figure 3-2: Relevant situations for different research strategies [YIN 1994, p. 6].

[11] *The studies were executed just after the decision to release the software was made.*

3.4 Approach

3.4.1 Surveys

Two surveys were used during the case studies. The first survey was used to get background information from the organisation undergoing a case study with respect to the characteristics of the organisation, the characteristics of the products developed, the characteristics of the market and a high-level description of the selected project(s).

The second survey was used to guide the interviews, in which the informants were asked their opinions and experiences. This survey addresses the study's questions as well as the formulated underlying questions. During each interview, additional questions were raised to obtain extra useful data or to clarify answers given.

3.4.2 Unit of analysis

As unit of analysis either a single software project or multiple projects in the organisation were chosen. Multiple projects were chosen if it could be reasoned that more relevant information can be obtained that way instead of using a single project. It might for instance be the case, that a supplier organisation distinguishes different types of projects. By taking these different project types together in one case study, chances will increase that more evidence can be obtained. Constraint here was that the effort needed to obtain this evidence did not increase significantly.

3.4.3 Selection criteria

The following criteria for selecting supplier organisations were used:

- Criterion 1: *Characteristics of the supplier organisation*
  - Maturity: documented policies and processes are in place
- Criterion 2: *Characteristics of the projects*
  - Functional product needs: medium to high
  - Reliability: important
  - Maintainability: important
  - Available budget: limited
- Criterion 3: *Characteristics of the market*
  - Lead-time or time to market: important
  - Level of competition: medium to high [12]

Criterion 1 was used to prevent the conduction of case studies in very unstable environments, where it will be hard to obtain consensus among the informants as well as supporting documentary evidence. The combination of Criterion 2 and Criterion 3 was used to select only those organisations in which making a trade-off decision between lead-time, functional product needs, reliability, pre-release cost (budget) and post-release cost (maintenance) is both important and complex.

As can be seen from these criteria in this phase of the study no choice was made for a specific investment type. Both commercial software suppliers and internal IT departments of for instance a financial or public organisation were considered. This is due to the exploratory nature of the case studies.

Eleven organisations were approached to participate in this phase of the project. Only seven organisations met the selection criteria and were finally selected. The results of all the selected case studies are presented in chapter 4.

[12] *Some supplier organisations deliver their developed products to the (parent) organisation itself, for instance in banking and insurance organisations. In this case, the market is considered to be an internal one and the criterion will not be used.*

3.5 Procedure

3.5.1 Preparation

In each selected case study an internal coordinator in the organisation of the software supplier was appointed, who served as the direct contact person during the entire case study.

The researcher and the internal coordinator prepared the case study by undertaking the following activities:

- Determination of the characteristics of the organisation, the products being developed and the market by using a survey.
- Determination of the unit of analysis (single project or multiple projects) and the project(s) to be involved.
- Selection of the informants to be interviewed. For each case study the following informants were considered to be important, of which at least three should be found in each case study:
  - Product manager, responsible for the entire lifecycle of the software application.
  - Project leader, responsible for the development of the software application.
  - Software architect, responsible for the design of the software architecture.
  - Project leader, responsible for the maintenance of the released software application.
  - Representative from the sales or marketing department, responsible for the search of the market place for the software application (prices, quantities, customer needs).
- Distribution of a brief description of the case study to all informants with the objective, the procedure and the categories of questions.
- Planning of the interviews (date and time, selection of appropriate interview room), the average time for interviews was 1.0 till 1.5 hours.
- Identification of the relevant documentation to be studied by the researcher (like process descriptions and minutes of meetings) before the interviews.

3.5.2 Interviews

Interviews were undertaken with one informant ('one on one') or with multiple informants[13]. Multiple informants in one interview were only allowed if they could speak freely (no political or hierarchical obstacles among the different informants). One of the reasons to have multiple informants in one interview session was that the unit of analysis involved more than one project. In that case informants of different projects fulfilling the same role (for instance project leader development) were allowed to attend in the same interview session.

Each interview was recorded (digital voice recorder).

The researcher started each interview by briefly explaining the informant(s) the objective and the procedure of the interview. Further relevant questions from the informant(s) were answered.

The researcher conducted the interview by asking questions, using the survey. The questions depended upon the role of the interviewee in an organisation and the specifically raised issues during an interview. The researcher, conducting the interview, could at any time decide to ask additional questions if he had the opinion that further relevant information could be revealed that way.

Every informant was free to give an answer, in case of irrelevant discussions between informants the researcher intervened. Aspects important to the researcher here were:

- *Respect*. The researcher respected the opinion of each informant and did not reveal his own opinion. The objective was to obtain relevant information. Further, it was important to establish a reliable relationship between researcher and informant(s) from the very beginning.
- *Style*. The questions had an open-ended nature there where possible, asking informants for the facts of matter as well for opinions. This contributed to seeing the person being interviewed as an informant and not a respondent [YIN 1994, p. 84].

[13] *This only happened in a very limited number of interviews.*

- *Reflexivity*. The researcher was aware of the fact that informants may have wanted to give the answer the researcher would have liked to hear [YIN 1994, p. 80].

At the end of the interview, each informant was given the opportunity to supply supplementary information on issues that to his opinion had not or had insufficiently been exposed.

3.5.3 Documentation

If regarded useful the researcher asked for documentation to be studied as well. Examples of documentation were the description of the software lifecycle used (including the release process) and the minutes of meetings where the release of a software application had been discussed. Also documentation describing the defined release criteria (as part of the software requirements or the project plan), describing the way these criteria had been deployed (as part of the architecture description) and describing the way these criteria had been evaluated (through inspections or tests) were of interest.

3.5.4 Report

As soon as all interviews of a particular case study had been conducted, the researcher wrote a case report within four weeks after the final interview. Each report described:

- Overview of the research project and scope of the case study.
- Organisation (products, role of software, selected project).
- Observations made, based on the interviews and documentation.
- Suggestions for improvements how the capability of the organisation with respect to releasing products could be improved. These were based on his findings in this study and were his personal opinions. As such, they will not be used further in the research project.

The case report was distributed to the interviewed persons by the coordinator of each participating organisation. The organisation was asked to agree formally to the contents of the case report within two weeks. In case of any opined errors, the researcher reacted within two weeks either by acknowledging and fixing the error or by demonstrating that there was no error. Case reports were only accepted if an undersigned copy of the report was returned to the researcher. In all cases, undersigned copies were obtained.

3.5.5 Confidentiality

The data obtained in each case study will remain confidentially. All interview reports and the final case reports have been archived by the researcher in a safe place and will be destroyed two months after the research project is ended. Each organisation participating in a case study is free to use the final case report internally and or externally.

4 Case Study Results

4.1 Introduction

In this chapter the results of the seven case studies are discussed. The names of the participating organisations are not revealed, as the selected projects and the organisational processes are in most cases considered to be of strategic importance.[14] For scientific purposes these anonymous descriptions are not considered to be a problem. All statements of each case study originate from the approved case study report of that particular case study and the actual name of the organisation is of little interest here. In this report the interpretation of the data by the researcher starts in this chapter by discussing and comparing the statements in the case study reports. It therefore remains perfectly auditable ([BER 1997, p. 52], based on [BOS 1988]).

Each case study is discussed separately before drawing overall conclusions. The following data is presented for each case study:

- *Description of the organisation, market characteristics, selected project(s) and product characteristics*. This information has been mainly derived from the first survey filled in by the organisation itself. Additional documentation like annual reports was used if found necessary.
- *Main observations*. This information summarizes the case study report using the following categories (detailed information of each case study can be found in the different final case study reports):
  - Definition of release criteria;
  - Deployment of release criteria;
  - Evaluation of release criteria;
  - Final release decision;
  - Post-release measurements.

  In each separate case study report it has been clearly described how the life-cycle model used in each organisation has been interpreted. For instance, in which phase of the project is the final release decision made? As a general rule, the following mapping has been used:

Definition of release criteria:	*during the start-up phase of the project*
Deployment of release criteria:	*after the start-up phase of the project till the testing phase*
Evaluation of the release criteria:	*after the start-up phase of the project till the final release decision*
Final release decision:	*the moment the product leaves the development project* [15]
Post-release measurements:	*as soon as the product has been officially rolled out to its users*

[14] *See also section 3.5, describing the confidentiality as agreed upon between the researcher and the participating organisations.*

[15] *Most participating organisations did not immediately roll out the product after it was released by the development project. In most case additional tests were conducted like production tests, beta tests and customer trials.*

4.2 Organisation A

4.2.1 Description

Organisation	*Participating organisation is one of the leading European insurance companies.*
Selected project(s)	*The selected project has developed the first version of a new administrative system to handle non-life related insurance claims.* *Reason to invest: development of new product to increase productivity.* *Business case available: very limited.*
Product characteristics	- *First version of a new software product.* - *High investment level (> Euro 10M).* - *Strategic importance.* - *Introduction of new development technologies and processes.*
Market characteristics	- *Principal market units are in a Western European country.* - *Customers are local agents within the same organisation.*

Figure 4-1: Description of Organisation A.

4.2.2 Main Observations

1. Definition of release criteria		
	Inputs	- *External inputs and constraints: not clearly defined (no good business case).* - *Internal inputs and constraints: defined in abstract terms (software life-cycle).*
	Stakeholders	- *Officially: Steering group at tactical level.* - *In practice: project leader and representatives from end-users.*
	Release criteria	- *Defined: lead-time, budget, functional product needs, compliance to external standards (prescribed architecture).* - *Not defined: non-functional product needs like reliability and maintainability, although considered important.*
	Priorities	- *Not documented.* - *No consensus amongst informants.* - *For future versions: lead-time expected to be less important.*
	Tradeoffs	- *No different project definition alternatives considered.*
	Decision process	- *Constructive and rational: finding consensus.* - *Negotiation skills and political issues: less important.*
2. Deployment of release criteria		
	Tradeoffs	- *No different product design alternatives considered.*
	Release criteria	- *Deployed: functional needs, lead-time, budget (continuously).* - *Not deployed: reliability and maintainability.*
3. Evaluation of release criteria		
	Release criteria	- *Evaluated: functional needs, lead-time, budget.* - *Reliability: only during integration and system testing.* - *Maintainability: not.* - *Compliance to external and internal standards: not.*
4. Final release decision		
	Objective	- *Attainable (release date postponed several times).*
	Stakeholders	- *Officially: Steering group at tactical level.* - *In practice: project leader and representatives from end-users.*
	Type	- *Nonroutine, nonrecurring.*
	Information	- *Available: spent lead-time, spent budget, implemented functional product needs, test results as an indication for reliability.*
	Constraints	- *Time and cost.*
	Quantifiable	- *Reliability and maintainability not quantifiable.*
	Environment	- *Open (not all variables known).*
	Decision process	- *Emotional due to time pressure: finding consensus.*
	Outcome	- *Very uncertain: operational cost not known.*
5. Post-release measurements		
	Maintenance	- *Corrective effort: no measurement system in place.* - *Defects: no analysis and feedback process.*

Figure 4-2: Main observations within Organisation A.

It was found that Organisation A met Criterion 1 of the selection criteria (section 3.3) only in a limited way. It was however possible to get a clear picture of the selected project as well as supporting documentary evidence. Therefore, the results of this case study are further used.

4.3 Organisation B

4.3.1 Description

Organisation	*Participating organisation is one of the world's leading companies in the area of document management.*
Selected project(s)	*The selected project has developed the first version of a new printing system.* *Reason to invest: strategic investment to enter market with new product.* *Business case available: yes.*
Product characteristics	- *First version of a new product (not only software).* - *High investment level (> Euro 10M).* - *Strategic importance.* - *Introduction of new product technologies.*
Market characteristics	- *High level of competition from few competitors.* - *Products are sold worldwide.* - *Customers are mainly professional users (business-to-business).*

Figure 4-3: Description of Organisation B.

4.3.2 Main Observations

1. Definition of release criteria		
	Inputs	- *External inputs and constraints: defined (business case).* - *Internal inputs and constraints: defined (software life-cycle).*
	Stakeholders	- *Steering group at tactical level.*
	Release criteria	- *Defined: lead-time, functional product needs, non-functional products needs, cost price, compliance to external standards.* - *Not defined: budget (considered to be of less importance).* - *Not defined: maintainability as a non-functional product need, although considered important.*
	Priorities	- *Documented (1. Lead-time, 2. Functionality[16], 3. Cost price).* - *No consensus amongst informants.* - *For future versions: lead-time expected to be less important.*
	Tradeoffs	- *No different project definition alternatives considered.*
	Decision process	- *Constructive and rational: finding consensus.* - *Negotiation skills and political issues: less important.*
2. Deployment of release criteria		
	Tradeoffs	- *No different product design alternatives considered.*
	Release criteria	- *Deployed: functional needs, lead-time, budget.* - *Not deployed: reliability and maintainability.*
3. Evaluation of release criteria		
	Release criteria	- *Evaluated: functional needs, lead-time, budget, compliance to external standards.* - *Reliability: only during integration and system testing.* - *Maintainability: not.* - *Compliance to internal standards: limited.*
4. Final release decision		
	Objective	- *Attainable (release date postponed several times).*
	Stakeholders	- *Steering group at tactical level.*
	Type	- *Nonroutine, nonrecurring.*
	Information	- *Available: spent lead-time, spent budget, implemented functional product needs, cost price, test results as an indication for reliability.*
	Constraints	- *Time and cost.*
	Quantifiable	- *Reliability and maintainability not quantifiable.*
	Environment	- *Open (not all variables known).*
	Decision process	- *Constructive and rational: finding consensus.*
	Outcome	- *Uncertain: operational cost not known.*
5. Post-release measurements		
	Maintenance	- *Corrective effort: limited measurement system in place.* - *Defects: no analysis and feedback process.*

Figure 4-4: Main observations within Organisation B.

[16] *'Functionality' complies to functional product needs.*

4.4 Organisation C

4.4.1 Description

Organisation	*Participating organisation is one of the world's leading companies in the area of telecommunications.*
Selected project(s)	*The product developed is a software platform on a digital telephone exchange, offering the facility to load intelligent network services.* *Reason to invest: investment to offer additional functionality.* *Business case available: yes.*
Product characteristics	- *Ninth revision of an existing product (near end of life).* - *Medium investment level (> Euro 1M, < Euro 10M).*
Market characteristics	- *High level of competition from few competitors.* - *Products are sold worldwide.* - *Customers are mainly network operators.*

Figure 4-5: Description of Organisation C.

4.4.2 Main Observations

1. Definition of release criteria	
Inputs	- *External inputs and constraints: defined (business case).* - *Internal inputs and constraints: defined in detail (software life-cycle).*
Stakeholders	- *Steering group at tactical level.*
Release criteria	- *Defined: lead-time, budget, functional product needs, non-functional products needs, compliance to external and internal standards.*
Priorities	- *No priorities: all criteria must be met without exceptions.* - *Reliability and maintainability are extremely important.*
Tradeoffs	- *No different project definition alternatives considered.*
Decision process	- *Constructive and rational: finding consensus.* - *Negotiation skills and political issues: not important.*
2. Deployment of release criteria	
Tradeoffs	- *Different product design alternatives considered.*
Release criteria	- *Deployed: functional needs, lead-time, budget.* - *Not deployed: reliability and maintainability, but very detailed design and coding rules available.*
3. Evaluation of release criteria	
Release criteria	- *Evaluated: functional needs, lead-time, budget, compliance to external and internal standards.* - *Reliability: via inspections, during integration and system testing.* - *Maintainability: not.*
4. Final release decision	
Objective	- *Attainable (release date postponed).*
Stakeholders	- *Steering group at tactical level.*
Type	- *Routine, recurring.*
Information	- *Available: spent lead-time, spent budget, implemented functional product needs, test results as an indication for reliability, compliance to external and internal standards.*
Constraints	- *Time and cost.*
Quantifiable	- *Reliability and maintainability not quantifiable.*
Environment	- *Open (not all variables known).*
Decision process	- *Constructive and rational: all set criteria must be met.*
Outcome	- *Relatively certain: minor changes implemented with respect to previous version and development processes have been prescribed in detail.*
5. Post-release measurements	
Maintenance	- *Corrective effort: limited measurement system in place.* - *Defects: limited analysis and feedback process in place.*

Figure 4-6: Main observations within Organisation C.

4.5 Organisation D

4.5.1 Description

Organisation	*Participating organisation is an independent business unit within a multinational, offering flexible staffing, projects and consultancy.*
Selected project(s)	*The product developed is a software product that provides facilities to transfer large volumes of data via a dedicated network. Product is developed for an external company (principal) and will be further maintained by that company after product release.* *Reason to invest: replacement of existing system to enable future enhancements.* *Business case available: no.*
Product characteristics	- *Fourth major version of an existing product (redesign).* - *Medium to low investment level (< 0.5M Euro).*
Market characteristics	- *Customers are businesses.*

Figure 4-7: Description of Organisation D.

4.5.2 Main Observations

1. Definition of release criteria		
	Inputs	- *External inputs and constraints: vaguely defined (no business case)* - *Internal inputs and constraints: defined.*
	Stakeholders	- *Steering group at tactical level.*
	Release criteria	- *Defined: lead-time, budget, functional product needs, non-functional products needs, compliance to internal standards.*
	Priorities	- *Documented in project management plan.* - *No consensus amongst informants.* - *For earlier versions: lead-time expected to have been more important.*
	Tradeoffs	- *No different project definition alternatives considered.*
	Decision process	- *Constructive and rational: finding consensus.* - *Negotiation skills and political issues: not important.*
2. Deployment of release criteria		
	Tradeoffs	- *Different product design alternatives considered.*
	Release criteria	- *Deployed: functional needs, lead-time, budget, portability.* - *Not deployed: reliability and maintainability.*
3. Evaluation of release criteria		
	Release criteria	- *Evaluated: functional needs, lead-time, budget,* - *Reliability: during integration and system testing.* - *Maintainability: not.* - *Compliance to internal standards: limited.*
4. Final release decision (not taken place yet, the expectations of the informants are summarized here)		
	Objective	- *Attainable (release date postponed several times).*
	Stakeholders	- *Steering group at tactical level.*
	Type	- *Routine, recurring with respect to the product.* - *Nonroutine, nonrecurring with respect to the transfer of the product responsibility to the principal.*
	Information	- *Available: spent lead-time, spent budget, implemented functional product needs, test results as an indication for reliability.*
	Constraints	- *Time and cost.*
	Quantifiable	- *Reliability and maintainability not quantifiable.*
	Environment	- *Open (not all variables known).*
	Decision process	- *Constructive and rational: finding consensus.*
	Outcome	- *Uncertain: operational cost not known.*
5. Post-release measurements		
	Maintenance	- *Corrective effort: measurement system in place.* - *Defects: limited analysis and feedback process in place.*

Figure 4-8: Main observations within Organisation D.

Note: this case study was difficult in the sense that two different release types were planned to take place. In the first place, it was planned to release the product by the supplier organisation to its principal. In the second place, it was planned to transfer the product responsibility from the supplier organisation to its principal. Further, at the time of the case study, the actual release decision of either type had not been made yet. Therefore, this case study will not be used in answering the case study questions.

4.6 Organisation E

4.6.1 Description

Organisation	*Participating organisation is one of the world's leading suppliers of instrumentation and software for X-ray analysis.*
Selected project(s)	*The product developed calculates and analyses the measured values obtained by X-ray fluorescence.* *Reason to invest: strategic investment to enter market with new product.* *Business case available: yes.*
Product characteristics	- *First version of a new product (not only software).* - *High investment level (> Euro 10M).* - *Strategic importance.* - *Introduction of new product technologies.*
Market characteristics	- *High level of competition from few competitors.* - *Products are sold worldwide.* - *Customers are professional users (business-to-business).*

Figure 4-9: Description of Organisation E.

4.6.2 Main Observations

1. Definition of release criteria		
	Inputs	- *External inputs and constraints: defined.* - *Internal inputs and constraints: defined.*
	Stakeholders	- *Steering group at tactical level.*
	Release criteria	- *Defined: lead-time, budget, functional product needs, non-functional products needs (including reliability and maintainability), cost price, compliance to external and internal standards.*
	Priorities	- *Documented (1. Quality, 2. Lead-time, 3. Functionality, 4. Budget).* [17] - *No consensus amongst informants.* - *For future versions: lead-time expected to be less important.*
	Tradeoffs	- *No different project definition alternatives considered.*
	Decision process	- *Constructive and rational: finding consensus.* - *Negotiation skills and political issues: not important.*
2. Deployment of release criteria		
	Tradeoffs	- *Different product design alternatives considered.*
	Release criteria	- *Deployed: functional needs, lead-time, budget.* - *Not deployed: reliability and maintainability.*
3. Evaluation of release criteria		
	Release criteria	- *Evaluated: functional needs, lead-time, budget, compliance to external standards.* - *Reliability: during integration and system testing.* - *Maintainability: not.* - *Compliance to internal standards: limited.*
4. Final release decision		
	Objective	- *Attainable (release date postponed several times).*
	Stakeholders	- *Steering group at tactical level.*
	Type	- *Nonroutine, nonrecurring.*
	Information	- *Available: spent lead-time, spent budget, implemented functional product needs, test results as an indication for reliability, compliance to external standards.*
	Constraints	- *Time and cost.*
	Quantifiable	- *Reliability and maintainability not quantifiable.*
	Environment	- *Open (not all variables known).*
	Decision process	- *Constructive and rational: finding consensus.*
	Outcome	- *Uncertain: operational cost not known.*
5. Post-release measurements		
	Maintenance	- *Corrective effort: limited measurement system in place.* - *Defects: limited analysis and feedback process in place.*

Figure 4-10: Main observations within Organisation E.

[17] *'Quality' complies to non-functional product needs and 'Functionality' complies to functional product needs.*

4.7 Organisation F

4.7.1 Description

Organisation	*Participating exchange organisation brings together participants, issuers and investors on an efficient and transparent securities market.*
Selected project(s)	*The product developed is a software platform, offering an electronic trading facility for stock market transactions.* *Reason to invest: investment to offer additional functionality.* *Business case available: yes (only cost, unable to allot benefits to product release).*
Product characteristics	- *Sixth major revision of an existing product.* - *Medium investment level (> Euro 1M).*
Market characteristics	- *Limited competition.* - *Customers are banks and investment companies, being participants of the exchange.*

Figure 4-11: Description of Organisation F.

4.7.2 Main Observations

1. Definition of release criteria		
	Inputs	- *External inputs and constraints: defined (business case).* - *Internal inputs and constraints: defined.*
	Stakeholders	- *Steering group at tactical level.*
	Release criteria	- *Defined: lead-time, budget, functional product needs, non-functional products needs (including reliability and maintainability), compliance to external and internal standards.*
	Priorities	- *Functional and non-functional product needs.* - *Not explicitly documented*
	Tradeoffs	- *No different project definition alternatives considered.*
	Decision process	- *Constructive and rational: finding consensus.* - *Negotiation skills and political issues: not important.*
2. Deployment of release criteria		
	Tradeoffs	- *No different product design alternatives considered.*
	Release criteria	- *Deployed: functional needs, lead-time, budget.* - *Not deployed: non-functional product needs like reliability and maintainability.*
3. Evaluation of release criteria		
	Release criteria	- *Evaluated: functional needs, lead-time, budget, compliance to external and internal standards.* - *Reliability: during integration and system testing.* - *Maintainability: not.*
4. Final release decision		
	Objective	- *Attainable (release date postponed).*
	Stakeholders	- *Steering group at tactical level.*
	Type	- *Routine, recurring.*
	Information	- *Available: spent lead-time, spent budget, implemented functional product needs, test results as an indication for reliability, compliance to external and internal standards.*
	Constraints	- *Time and cost.*
	Quantifiable	- *Reliability and maintainability not quantifiable.*[18]
	Environment	- *Open (not all variables known).*
	Decision process	- *Influenced by political issues between different stakeholders.*
	Outcome	- *Relatively certain: minor changes implemented with respect to previous version.*
5. Post-release measurements		
	Maintenance	- *Corrective effort: measurement system in place.* - *Defects: no analysis and feedback process in place.*

Figure 4-12: Main observations within Organisation F.

[18] *Although the levels of reliability and maintainability could not be quantified for this product version, they have been specified for the version of the product and measured afterwards for previously released versions. As the changes in this version are limited, the organisation felt comfortable that the levels could still be met after having performed some dedicated tests.*

4.8 Organisation G

4.8.1 Description

Organisation	*Participating organisation is a leading global financial services company.*
Selected project(s)	*The product developed covers a set of various mortgage-related products.* *Reason to invest: replacement of existing system to increase productivity.* *Business case available: yes.*
Product characteristics	- *First version of a new product (replacement).* - *High investment level (> Euro 10M).*
Market characteristics	- *No competition.* - *Customers are local agents within the same organisation.*

Figure 4-13: Description of Organisation G.

4.8.2 Main Observations

1. Definition of release criteria		
	Inputs	- *External inputs and constraints: defined (business case).* - *Internal inputs and constraints: defined.*
	Stakeholders	- *Steering group at tactical level.*
	Release criteria	- *Defined: lead-time, budget, functional product needs, non-functional products needs (especially reliability, maintainability and performance), compliance to internal standards.*
	Priorities	- *Not documented.* - *No consensus amongst informants.* - *For future versions: lead-time expected to be less important.*
	Tradeoffs	- *No different project definition alternatives considered.*
	Decision process	- *Constructive: finding consensus.* - *Negotiation skills and political issues: considered important.*
2. Deployment of release criteria		
	Tradeoffs	- *Different product design alternatives considered.*
	Release criteria	- *Deployed: functional needs, lead-time, budget.* - *Not deployed: reliability and maintainability.*
3. Evaluation of release criteria		
	Release criteria	- *Evaluated: functional needs, lead-time, budget, compliance to internal standards.* - *Reliability: during integration and system testing.* - *Maintainability: not.*
4. Final release decision		
	Objective	- *Attainable (release date postponed).*
	Stakeholders	- *Steering group at tactical level.*
	Type	- *Routine, recurring.*
	Information	- *Available: spent lead-time, spent budget, implemented functional product needs, test results as an indication for reliability.*
	Constraints	- *Time and cost.*
	Quantifiable	- *Reliability and maintainability not quantifiable.*
	Environment	- *Open (not all variables known).*
	Decision process	- *Constructive and rational: finding consensus.*
	Outcome	- *Uncertain: operational cost not known.*
5. Post-release measurements		
	Maintenance	- *Corrective effort: no measurement system in place.* - *Defects: no analysis and feedback process in place.*

Figure 4-14: Main observations within Organisation G.

In this case study, a second project was observed as well. This project developed an IT-infrastructure for other projects, also strategically important and also with a high investment level. The observations in this second project confirmed the observations listed above. In the resulting case report for his organisation, only the results of the first project were listed.

5 Conclusions with respect to Case Study Questions

5.1 Introduction

In this chapter the results of the different case studies are summarized in order to answer the earlier raised questions in chapter 3.

5.2 Case Study Questions

1.a How can the release decision be characterized?

- *How can the release decision be characterized with respect to routine, recurrence and certainty of the outcome?*
  The release decision was found to be either a routine, recurring decision with a high degree of certainty (cases C, F) or a nonroutine, nonrecurring decision with a high degree of uncertainty (cases A, B, E, G).

- *Is this characterization influenced by factors like the phase in the product's lifecycle or the strategic importance of the product?*
  The nonroutine, nonrecurring decisions appeared in new or first product developments (cases A, B, E, G). Routine, recurring decisions were found for subsequent versions of software products (cases C, F). The reasons to invest or investment types were very different. The strategic importance for all new product development was high and the investment level was high. For the subsequent product developments, the strategic importance was medium as well as the investment level. Figure 5-1 gives an overview.

	Reason to invest	Decision	Product version	Strategic importance and investment level
Organisation A	development of new system to increase productivity	nonroutine, nonrecurring	First	high
Organisation B	strategic investment to enter market with new product	nonroutine, nonrecurring	First	high
Organisation D	investment to implement additional functionality	routine, recurring	Subsequent	medium
Organisation E	strategic investment to enter market with new product	nonroutine, nonrecurring	First	high
Organisation F	investment to implement additional functionality	routine, recurring	Subsequent	medium
Organisation G	replacement of existing system to increase productivity	nonroutine. nonrecurring	First	high

Figure 5-1: Overview of results of case studies with respect to the characterisation of the release decision.

The conclusion is drawn here, that the characterisation of the release decision is influenced by the phase in the product's lifecycle as well as the strategic importance and investment level. If a new product is developed and the strategic importance and investment level are high, the release decision will be a nonroutine, nonrecurring decision. For subsequent product versions with medium strategic importance and investment level, the release decision will be a routine, recurring decision. For new product developments with a low to medium strategic importance and for subsequent product developments with a high strategic importance it is not clear whether the release decision will be either routine/recurring or nonroutine/nonrecurring. These cases were not studied. See also Figure 5-2.

The conclusion is: a release decision can be both a Category I and a Category II decision. It was found that the category depends on the phase in the product's lifecycle and the strategic importance (with associated investment level) of the product to the organisation.

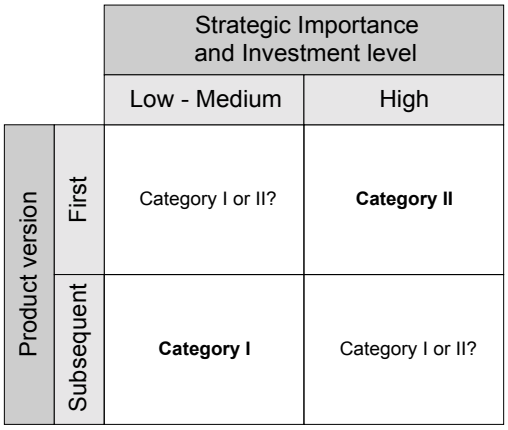

Figure 5-2: Decision category as a function of product version and strategic importance.

An additional observation made is the following. Harrison states that the decision category determines at which level in an organisation a decision is to be made [HAR 1987, p. 23]. Higher management must concentrate on nonroutine decisions (Category II), routine decisions must be left to operating management (Category I). In the case studies this difference was not found, the stakeholders involved were mainly representatives at tactical level. An explanation might be the following. A release decision will often involve the co-ordination between different departments within an organisation, enforcing decision-making at a tactical level. Another important reason to involve stakeholders at tactical level is that their high level support for the product from the development stage to its launch to the market is found to be a success factor for successful product innovation (see for instance [MAI 1984] and [ROT 1974]).

1.b Can the decision to release a product be described with one of the four decision-making models of Harrison [HAR 1987]?

- *What is the nature of the objective(s) of the decision (fixed, attainable, limited or highly dynamic)?*
  The nature of the objective of the final release decision turned out to be attainable in all cases in the sense that defined release criteria were not fixed.[19] Deviations from the originally stated product needs and constraints were for instance: the planned release date was postponed, the functional product needs were decreased, the non-functional product needs were not met, product and the used development processes did not comply with the stated standards. The allowance of these deviations does not imply that the nature of the objective is highly dynamic. Developing software product is or should be a highly structured and predictable process as it involves a lot of co-ordination between different groups inside and outside a supplier organisation.

- *Which information is available to make the decision? Is it limited or unlimited?*
  In all cases the information available to make the final release decision was limited. In all cases, the exact levels of reliability and maintainability were not precisely known. This makes it impossible to accurately predict the operational cost when the product is transferred to its intended users. This was found to be especially true for new products (cases A, B, E, G). For subsequent versions of existing products with relatively minor changes (cases C, F), there was a proven record available of how previous versions of the product behaved in operation.

- *Are there cognitive limitations?*
  During the case studies it has not been explicitly addressed whether or not cognitive limitations exist. The fact that the release decision was in all cases made by a group of individuals automatically implies that cognitive limitations play a role [HAR 1987, pp. 159-160]:

[19] *The following definition is used for the objective of a release decision: "Release the product in such a way that it meets the stated products needs and constraints". This implies that a product is released at the stated date, meeting the stated functional and non-functional products needs, complying to the external and internal standards, and developed within the available budget.*

> *Although facts are universal, the interpretation of them is not. Interpretation is personal. It is dominated by concepts, beliefs, values and ideas brought to the analysis. The filtering process of human perception can differ from reality by including observations that are not real or by omitting them …*

In section 7.3, this topic will be further discussed by giving examples of cognitive constraints.

- *Are there cost and time constraints?*
  In all cases, there were cost and time constraints to retrieve complete and reliable information. Although in most cases considerable time and cost were spent on integration and system testing to detect possible defects and to verify that the functional product needs were implemented well and that a 'sufficient' level of reliability had been obtained, the available resources were not unlimited. It has not been explicitly investigated in the case studies, but it is obvious that the organisations consciously or unconsciously try to reach the *point of optimality*. Beyond this point, obtaining additional information would lead to a diminishing value. See Figure 5-3.

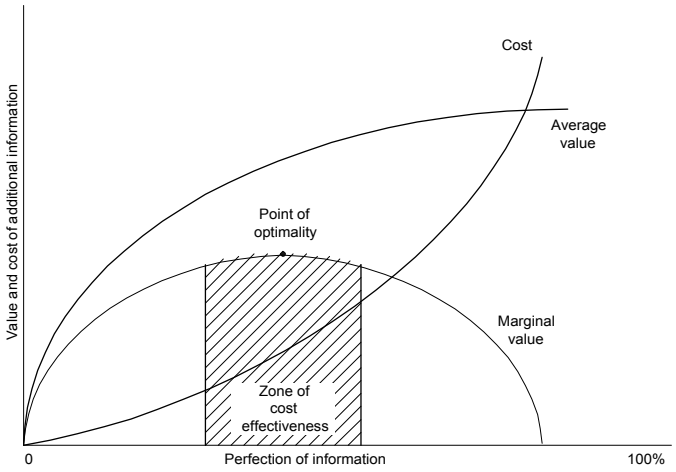

Figure 5-3: Cost of additional information [HAR 1987, p. 49].

- *To which extent are the release criteria quantifiable?*
  In all cases, not all release criteria could be quantified. It is for instance difficult to quantify the compliance to standards other than on an ordinal scale like: *no – partially - yes*. Further, in all cases it turned out to be not possible to evaluate accurately the levels of reliability and maintainability in a quantitative way on a ratio scale. This does not imply that the number of alternatives is exhaustive or transitive. In practice, a limited number of alternatives with respect to the release decision will be discussed (see also section 2.3):
  - Release now.
  - Release later after the successful implementation of some corrective actions.
  - Do not release the product and cancel the project.

- *Is the environment open or closed?*
  In all cases, the environment was open. It is practically impossible to control all possible variables completely as release decision-making is not a contrived situation.

- *Is the outcome limited in qualitative and quantitative terms?*
  As in all cases the levels of reliability and maintainability are not precisely known, the outcome of the release decision is limited in quantitative terms. It will be impossible to accurately predict the operation cost for instance for corrective and perfective maintenance activities. Further, there are qualitative limitations as well. What is the effect on the outcome in qualitative terms for instance if the internal standards have only been partially met?

The obtained results are presented in Figure 5-4 (coloured cells denote a match). It shows the key assumptions as discussed above (*Objectives – Outcome*), one key ingredient *(Horizon*) and the primary decision-making criterion (*Primary criterion*) [HAR 1987, p. 152]. As can be directly learned from

Figure 30, release decision-making for software products can best be described with the Organisation Model of Harrison. The key ingredient *Horizon* has been taken into account to stress the difference between the Organisational Model and Process Model. Release decisions have a short-term horizon and not a long-term horizon. According to Harrison: the Organisational Model is geared toward quick changes in decisions or tactical adjustments when it becomes apparent that difficulties are encountered at the point of implementation when trying to meet the attainable objectives [HAR 1987, p. 158]. The Process Model is strategic in its orientation. One could argue here that the Political Model also applies to some extent. The principal difference is however that the Political Model aims toward an outcome that is acceptable to many external constitutions, whereas the Organisational Model is geared to outcomes that benefit the organisation [HAR 1987, p. 156]. Further, the test of a good decision is whether most of the decision makers agree on the likely outcome and important outcomes, alternatives, and values are neglected in the Political Model.

	Rational (classic)	Organisational (neoclassical)	Political (adaptive)	Process (managerial)
Objectives	fixed	**attainable**	limited	highly dynamic
Information	unlimited	**limited**	**limited**	**limited**
Cognitive limitations	no	**yes**	**yes**	**yes**
Time and cost constraints	no	**yes**	**yes**	**yes**
Alternatives	quantifiable and transitive	**partially quantifiable and intransitive**	nonquantifiable and generally transitive	generally nonquantifiable and intransitive
Environment	closed	**open**	**open**	**open**
Outcome	quantitatively limited	**qualitatively and quantitatively limited**	environmentally limited	objectives-oriented
Horizon	**short-term**	**short-term**	**short-term**	long-term
Primary criterion	Maximized outcome	**Satisfying outcome**	Acceptable outcome	Objectives-oriented outcome

Figure 5-4: Results of the case studies with respect to decision-making models.

Conclusion is that the decision to release a product can be described with one of the decision-making models of Harrison: the Organisational Model. This corresponds with the earlier conclusion, that a release decision is either a Category I or a Category II decision. The Organisational Model accommodates both decision types [HAR 1987, p. 155], whereas the Rational Model is primarily suited for Category I decisions.

2. Can the outcome of the release decision be expressed in financial terms?

- *Are the release criteria at project level deployed to the identified components in the selected design?*
  Criteria like functional product needs, lead-time and budget were in all cases deployed to the identified components in the selected design. However, only in case G evidence was found that during the product design phase time and effort was spent to deploy non-functional product needs like reliability and maintainability to identified components.

- *How are the values of release criteria evaluated?*
  Lead-time and budget were in all cases continuously evaluated by measuring the elapsed time and spent effort. In most cases, an independent software quality assurance group verified the compliance to standards. It turned out to be difficult to evaluate non-functional product needs like reliability and maintainability. After selecting the product design and before starting integration and system testing there was no or little attention to evaluate these non-functional product needs. During integration and system testing there was in all cases a strong focus on evaluating the level of reliability. No cases were found in which the expected level of maintainability was evaluated.

- *To which extent are the release criteria quantifiable and can they be completely and reliably evaluated?*

As discussed earlier, not all release criteria could be quantified. This is true for the compliance to standards (scale problem), but also the levels of reliability and maintainability could not be completely and reliably evaluated. Some organisations use for reliability defect density measures (number of defects found related to the product size), others use Mean Time Between Failures (MTBF, in hours) or Availability (defined for instance as: MTBF / (MTBF + MTTR), where MTTR stands for Mean Time To Repair).

- *To which extent can the evaluated release criteria be expressed in financial terms?*
  The fact that not all release criteria could be quantified, also makes it difficult to express the evaluated release criteria in financial terms. But even when attempts were made to assign a value to for instance the level of reliability through evaluation, the conversion to financial terms could not be made. No situations were found where the estimated level of reliability was expressed in financial terms, like:
  - What would the impact be on sales figures when the reliability expressed in Mean Time Between Failures is 950 hours instead of 1000 hours?
  - What is the average amount of effort and lead-time to solve a certain defect type?

Conclusion is that the outcome of the release decision could not be fully expressed in financial terms, only in a limited way. This conclusion also corresponds with the earlier conclusion, that the decision to release a product can be described with the Organisational Model: the outcome is qualitatively and quantitatively limited. It can even be argued that in practice, expressing the outcome in financial terms cannot be done without introducing uncertainties. The environment is always open, cognitive limitations will exist (restricting for instance the amount of 'consumable' information), and it is unrealistic to assume that organisations will not bear time and costs constraints.

3. Can prioritised release criteria be used to select alternatives?

- *What are the priorities of the release criteria in the current project?*
  In the different cases different priorities were found for the release criteria. See Figure 5-5. In cases A, F and G they were not explicitly documented and in cases A, B, E and G no consensus was found amongst the different informants in the same organisation.

	Product version	Priorities of release critera		
		Order (high -> low)	Documented	Consensus
Organisation A	First	unknown	no	no
Organisation B	First	lead-time, functionality, cost price	yes	no
Organisation C	Subsequent	all product needs and constraints	yes	yes
Organisation E	First	quality, lead-time, functionality, budget	yes	no
Organisation F	Subsequent	functional and non-functional product needs	no	yes
Organisation G	First	unknown	no	no

Figure 5-5: Priorities of the release criteria as found in the different case studies.

- *Do they correspond to the model of Moore?*
  In cases A, B, E and G new products were developed. Lead-time was considered important as the most important criterion in case B, but not in case E where quality was considered most important. For cases A and G, the situation was not clear. In cases C and F subsequent versions of existing products were developed. Both functional and non-functional products needs were considered important.
  In practice, it was found however in all cases that near the end of product development towards the final release moment, there was a very strong focus on reliability. This was both true in the

cases where new products and subsequent versions of existing products were developed. In case B for instance, it was stated during the interviews and later discussions about the final case study report, that the organisation has a reputation to hold that their products are reliable, irrelevant to the question whether it is a new product or not. Another important observation was that in all cases maintainability has been mentioned as a release criterion. However, during product implementation and test, no explicit evaluation of this criterion has taken place in any of the cases.
The conclusion is that the model of Moore with regard to the priorities of release criteria is not generally applicable to all possible situations. It may be true in some cases, but it heavily depends on factors like the characteristics of the market and the reputation and competitive positions of a supplier organisation.

- *What are the criteria and their priorities used to select (search for, compare and evaluate) different alternatives?*
  As discussed in section 2.3, three important moments can be distinguished during software product development to search for, compare and evaluate different alternatives: during project definition, during product design and towards the product release decision. In nearly none of the cases, explicit evidence was found that alternatives are searched for, compared and evaluated using the set of prioritised release criteria. Only in cases C, E and G different product designs were searched for, compared and evaluated. The criteria used were lead-time, budget, functional product needs and non-functional product needs (not all of them, but a subset). In many cases, it was observed that supporting methods, techniques and models are known but not used. It has not been investigated what the reasons are for not using them.

- *To which extent do these selection criteria correspond to the release criteria?*
  In all cases, the found design evaluation criteria were part of the set of release criteria.

The conclusion is that no evidence has been found that release criteria and their priorities cannot be used to select alternatives during the different development stages. However, in practice it has been difficult to observe what the exact order of the criteria is. There are often not documented and differently perceived by different people in the same project. Further, only in a limited number of cases alternatives were searched for, compared and evaluated.

6 Overall Conclusions

6.1 Introduction

In this chapter the overall conclusions are summarized with respect to the raised questions. Additional observations that are considered to be useful for the remainder of this study are listed as well. The conclusions are to see whether the assumptions underlying the central research question could be validated or not. This leads to a redefinition of the central research question as well as the formulation of relevant sub questions.

6.2 Summary of Case Studies

The conducted case studies have revealed clear answers to the formulated questions. Summarized, the conclusions are:

- *Conclusion 1.a*: A release decision can be both a Category I and a Category II decision. The category depends on the phase in the product's lifecycle and the strategic importance (with associated investment level) of the product to the organisation.
- *Conclusion 1.b*: The decision to release a product can be described with one of Harrison's decision-making models: the Organisational Model.
- *Conclusion 2*: No evidence has been found that a release decision can be entirely expressed in financial terms, only in a limited way. It has been argued, that in practice it will be very difficult to do so without introducing uncertainties.
- *Conclusion 3*: No evidence has been found that release criteria and their priorities cannot be used to select alternatives during the different development stages.

These conclusions can be used to verify or falsify the assumptions of section 3.2.

- *Assumption 1*. The objective of a release decision is to maximize the resulting economic value.

  This assumption is rejected (Conclusion 1.b, confirmed by Conclusion 1.a) as the primary decision-making criterion of the Organisational Model is satisfying outcome and not maximized outcome.

- *Assumption 2*. The economic value can be calculated, in other words the variables that determine the economic value can be expressed in financial, quantitative terms.

  This assumption is also rejected (Conclusion 2).

- *Assumption 3*. If the objectives of the release decision have been predetermined in a managerial decision-making process, the criteria used must be available prior to the release decision in order to steer product development into the right direction. They must support the selection of different alternatives during the different stages of product development, after project definition.

  This assumption could not be falsified (Conclusion 3).

6.3 Further Interpretation of the Results

The conclusions of the case studies were used to verify the assumptions underlying the central research question. However, it is considered interesting as well to review the control system of section 2.4 here. This control system describes a business-case driven approach to software product development. During the interviews the control system turned out to be very useful to steer questions and clarify answers. In various cases the control system was later used to illustrate the organisation's strengths and weaknesses.

In this section the control system is used in the same way, now by summarizing the overall weaknesses found [SAS 2003]:

- *Alignment between business case and project*. In all cases except case A, a business case was used as the rationale for a project, stating both the expected cost and benefits.[20] During the project however, in most cases the Project Steering Committee and the Software Development Team failed to inform each other explicitly about the current status of the business case (new insights) and the current status of the project (progress so far and estimates to completion).
- *Comparison and evaluation of alternatives*. This happened in most cases implicitly, however at crucial decision moments (defining the project scope, selecting the product design) no evidence was found why one alternative was selected above the other, using criteria derived from the business case. Available methods and techniques for comparison and evaluation (like project calculation methods and architecture evaluation methods) were in most cases known but not used.
- *Estimation of operational cost*. In all cases, reliability and maintainability were considered to be important non-functional product needs as they determine to a great extent the operational cost after product release. High reliability reduces corrective maintenance effort and high maintainability reduces both corrective maintenance effort and adaptive/perfective maintenance effort. In nearly all cases, these non-functional needs were not deployed to lower level components as identified in the selected product design or software architecture. It was only during testing that much effort was spent on trying to meet a high level of reliability. No cases have been found where the level of maintainability was evaluated. In all cases reliability and maintainability could not be expressed in financial terms.
- *Evaluation of business case and project.* After the final product release, there were no specific actions undertaken to evaluate the result of the business case as a whole and the results of the implemented decisions at crucial moments during development (defining the project scope, selecting the product design, releasing the product). Only in case G a plan was available to evaluate the business case at predefined moments after product release by the chairman of the Project Steering Committee, who was assigned the responsibility for the investments made. In all cases, there was no defined process in place to analyse the defects found after product release and to use the results to remove process deficiencies in product development.

In Figure 6-1, the results are illustrated in the used control system.

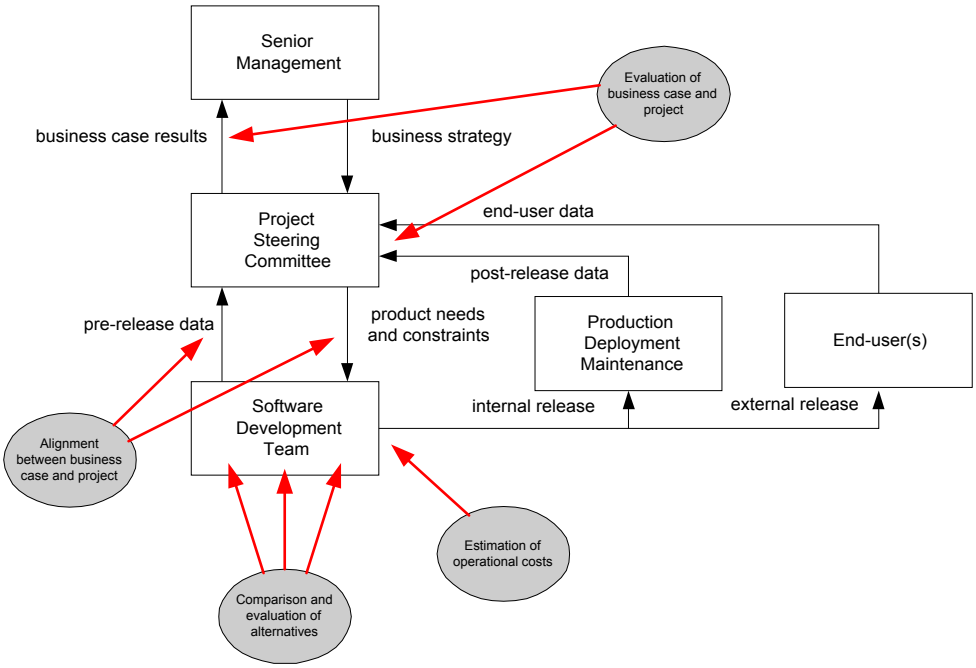

Figure 6-1: Results of the case studies, presented in the control system.

[20] *In case F it was found impossible to allot benefits to a specific product release, as the clients of the product pay an annual fee for a larger set of products or services.*

It is recalled here that the control system used was originally derived from the systems theory of control (see section 2.3). This theory states five requirements for effective control. Assessing the effectiveness of these requirements with the results of the case studies gives the following outcome:

	Requirement	Case study results
1	Goal	Absence of a documented set of prioritised release criteria, which can be seen as the goals. No consensus about the priorities of the release criteria.
2	Model	Limited understanding of the effects of taking control measures on the outcome of the project, found to be especially true for reliability and maintainability.
3	Information	No update of the business case with respect to changes in the market. No alignment of the project status with the business case.
4	Measures	No situations found were the measures itself were seriously limited.
5	Capacity	No situations found were the capacity for data handling was seriously limited.

Figure 6-2: Case study results mapped on the requirements for effective control

From this overview, it can be derived that the fulfilment of the first three requirements is in general weak. The absence of clear goals of release criteria, not having available a model to predict the effect of control measures and the lack of sufficient information hampers the effectiveness of the other two requirements.

The results can also be visualised in another way. Ideally, a project starts with no uncertainty at all. This must be considered however as a utopia. There is always some uncertainty present with respect to one or more release criteria. Suppose, distinction is made between the following release criteria: products needs (functional and non-functional), constraints, lead-time, budget and compliance to standards (external and internal) [21]. It would be a preferred situation if the level of uncertainty of each of the release criteria would be reduced when the project progresses. A well-balanced project plan would have incorporated the uncertainties in such a way, that they compensate each other and the planned release date is met. See Figure 6-3.

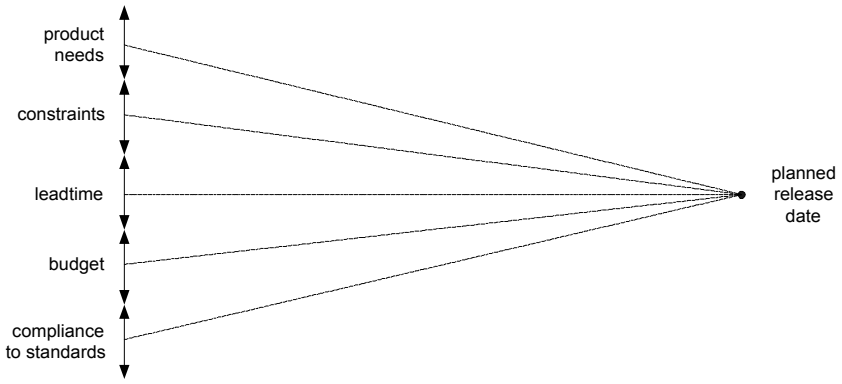

Figure 6-3: Preferred scenario, where uncertainty levels are reduced continuously during a project.

What is often found in practice however is that at the start of the project there is still a high level of uncertainty regarding the release criteria. Some of them may even not have been defined. At a certain moment in time it is decided to re-plan the release date, due to unexpected surprises. At that moment there will already be a time pressure, causing that there is a strong focus on the short-term objective *deliver as soon as possible as much functional needs that meet the most essential external standards*. There are cases where even the budget is increased to assign more people to the project trying to meet this objective. Consequences will probably be that re-planning will again be necessary and that no attention is given anymore to meeting the non-functional needs (especially reliability and maintainability) and compliance with the internal standards. When the product is finally released, the

[21] *Lead-time, budget and compliance to standards have been made explicit here.*

exact status of the product and other aspects may even be unknown. See Figure 6-3. The organisation will probably not take the time to analyse and repair the situation after the product release, as it will be forced to release new versions to improve the non-functional needs (reliability) and implement additional functionality that had been skipped. Further, future maintenance activities will be hampered as maintainability has not been addressed during the initial release and the internal standards have not been met.

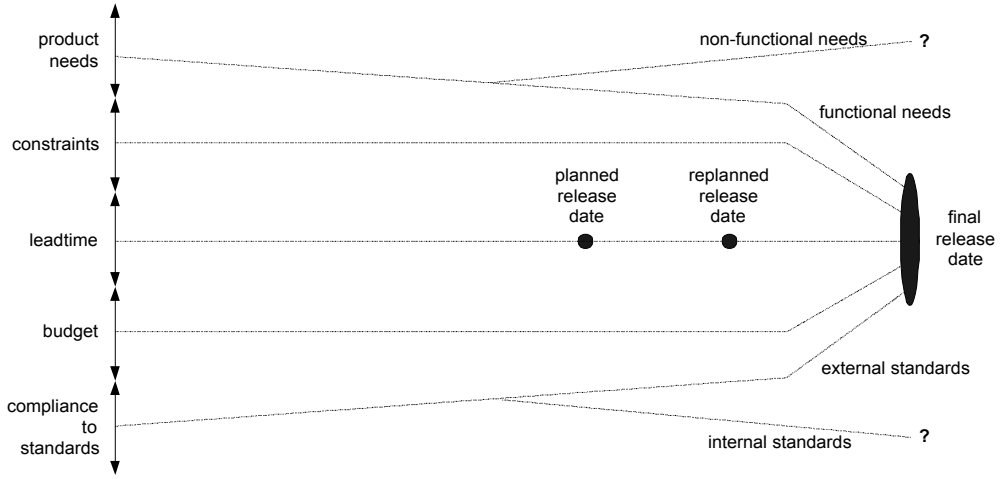

Figure 6-3: Doom scenario, where levels of uncertainty remain present throughout the project.

6.4 Adjusted Research Question

The conclusions and results as described in the previous sections are used to reconsider the central research question as formulated in section 3.1. Three issues are raised here to adjust the question:

- Conclusion I states that the Organisational Model applies to release decisions. The decision is made in an open environment where the information is imperfect, where time and cost constraints exist as well as cognitive limitations: it is a context of bounded rationality [HAR 1987, p. 97]. This implies there cannot be an *optimal economic moment.* The term *optimal* must be replaced by *satisfying*.
- Conclusion 2 states that the outcome of a release decision can hardly be fully expressed in financial terms (only in a limited way). The absence of a fully financial evaluation enforces the effects of group behaviour as more room is created for discussions and negotiations. It is inevitable that the stakeholders will have different positions and different preferences with respect to the outcome.[22] A marketing manager may for instance prefer to release the software product as early as possible in order to satisfy the promises he has made to his clients. The person responsible for maintenance may want to delay the release decision if the development documentation is not ready yet. The *effects of group behaviour* must be neglected and will be taken into account. It would go beyond the scope of this study to look into cognitive limitations, influencing individual behaviour of each decision-maker, as well. It is however important to be aware of their presence.
- Despite previous issues, it can still be argued that developing a software product is an economic or investment activity. Independent of the type of investment there will be pressure to limit the cost to an acceptable level and raise benefits. It can then also be argued that making a release decision is an *investment activity*. The earlier made investment proposal (business case) is in fact reviewed again. The difference is that investments have been made during development and that development time has elapsed. The question remains however whether investments should proceed or not. This review of the business case can be performed during different development stages. Conclusion 3 supports this argumentation: a set of prioritised release criteria will facilitate the selection of alternatives throughout product development. Hereby, an economic perspective can be chosen. Using the Organisational Model instead of the Rational Model does

[22] *According to Allisin, even when the outcome of a release decision could be fully quantified, the preference functions of the stakeholders will tend to defy quantification if the proposed alternative does not rank highest in the stakeholder's payoff function [ALL 1971].*

not mean that available economic methods, statistical techniques and mathematical models are of no use. These ingredients of the Rational Model facilitate decision-making in a context of bounded rationality [HAR 1987, p. 153]:

- Combining estimates of outcome uncertainty, expressed as subjective probabilities, with outcome consequences help to measure the desirability of an alternative.
- They guide the search process for alternatives.
- They provide a basis for reducing the number of relevant alternatives.

Taking into account the issues as raised above the central research question is redefined as:

How to specify a method that can be used to determine a satisfying economic moment to release a software product, assuming that a release decision is an investment activity and taking into account the effects of group behaviour?

Related sub questions are:

- Which methods, techniques and models can be used during software product development to support economic decision-making when to release a software product and how do they interrelate to each other?
- What are specific criteria to an organisation and its group of decision-makers to adopt these methods, techniques and models? [23]
- How can the effects of group behaviour during decision-making be recognized and how can the negative consequences be reduced or eliminated?

This redefined research question means that two different perspectives will have to be addressed in the method to be developed. In the first place, the method will concentrate on the disciplines *Economics and Statistics* and *Mathematics*. Secondly, the method must take into account the effects from the disciplines *Sociology* and *Social Psychology*, addressing group behaviour. See also Figure 6-4.

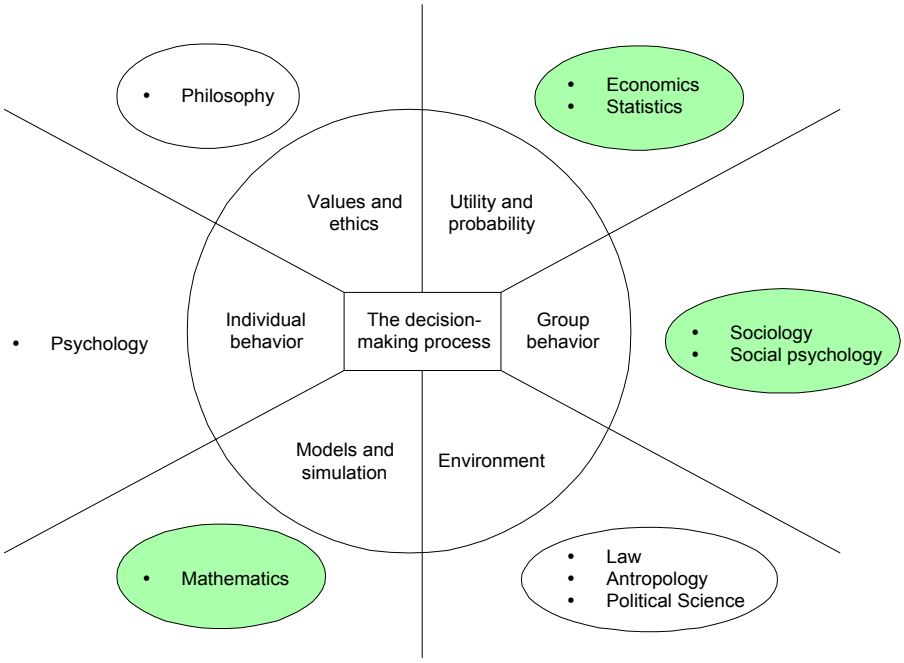

Figure 6-4: Interdisciplinary framework for decision-making [HAR 1987, p. 160].

In the next chapter some initial ideas of the researcher will be given.

[23] *See for instance section 6.3 where it was concluded that methods for comparison were known but not used.*

7 Towards a Conceptual Method

7.1 Introduction

In the previous chapter it was concluded that the method to be specified concentrates on the disciplines *Economics*, *Statistics* and *Mathematics* as well as on the disciplines *Sociology* and *Social Psychology*. These two perspectives will from now on be referred to as the *Quantitative Perspective* and the *Behavioural Perspective*. They are further discussed in the next two sections. Hereafter, some introductory remarks are made about adoption theory of new innovations. Finally, the context will be described in which the Conceptual Method can be applied: the preconditions.

7.2 Quantitative Perspective

7.2.1 Multi-attribute Decision-making Models

The *Quantitative Perspective* combines the disciplines Economics, Statistics and Mathematics. The most important discipline in this research is Economics as the method is to specify a method that can help to determine a satisfying economic release moment. There is a strong focus on trying to maximize the economic outcome or utility, which is the basis to choose amongst alternatives. In the absence of perfect information, but with limited knowledge of possible outcomes, some risk must be assumed. Risk is made acceptable by assigning subjective probabilities, which is the area of Statistics. The alternative with the highest expected value for maximizing the utility is chosen. Difference techniques can be used to determine the highest expected value. The discipline of Mathematics appears through the development of models to simulate real-life situations.[24]

For both the disciplines Statistics and Mathematics distinction can be made between *deterministic* techniques or models (same inputs result in same outputs) and *probabilistic* techniques or models (frequency distribution of output values through distribution of inputs around some average value) [HAR 1987, p. 169]. It is assumed here that the usage of decision trees is also a probabilistic technique.

Regarding statistical techniques, the most commonly used deterministic techniques are multi-attribute decision-making models (MADM). They can be seen as models of choice in the decision-making process as described by Harrison (discussed in section 2.2) when there is not one common denominator such as a monetary number and where the set of decision alternatives has been predetermined.[25] Harrison describes as the principal models of choice ([HAR 1987, pp. 58-59], based on [HOG 1980]):

- *Linear model*. This is a straightforward, measurable compensatory[26] model. Each dimension or variable in this model is quantified and is given a weight reflecting its relative importance. The evaluation of each alternative is then the sum of the weighted values on its dimensions. The alternative with the greatest sum for all dimensions is the obvious choice.
- *Disjunctive model*. This is a compensatory model. The approach to choice seeks the best attribute or characteristic that is presumed to denote the best alternative. In this model the decision-maker will permit a low score on a dimension provided if there is a very high score on one of the other dimensions. The alternative with the highest rating in its best characteristic is chosen.
- *Conjunctive model*. This is a non-compensatory model. It is one in which the decision-maker sets certain cut-off points on the dimensions such that any alternative that falls below a cut-off is eliminated.

[24] *In other literature, other definitions of these disciplines may be found. Others might for instance not make a distinction between a statistical technique or a mathematical model. As in this report and in the later study many different methods, techniques and models will be discussed, it seems however appropriate to use a consistent set of definitions, clearly distinguishing between the different disciplines.*

[25] *No attention is given here to multiple objective decision-making models (MODM), where decision variables are infinitely and subject to constraints. These problems may be solved by linear programming.*

[26] *A compensatory model means that a decision-maker is willing to allow compensation: a strong performance on one criterion can be compensated by a weak performance on some other criterion.*

- *Lexicographic model*. This is a non-compensatory model. The model first ranks the characteristics in order of importance and then selects the alternative rated best on the most important characteristic. If two or more alternatives rate equally, the next most important characteristic is used.
- *Elimination-by-aspects model*. This is combination of the three above-mentioned models (disjunctive/conjunctive and lexicographic models). The model assumes that alternatives consist of a set of aspects or characteristics. At each stage of the process one characteristic is elected according to a probabilistic scheme and alternatives that do not include the aspect are eliminated. The process continues until only one alternative remains.

In literature, many variants and specific implementations can be found. De Vries [VRI 1992] and Triantaphyllou [TRI 2000] give an overview of different methods. Examples are:

- Linear model: SMART [EDW 1994].
- Outranking methods[27]: Electre [ROY 1991] and TOPSIS [HWA 1981].
- Outranking methods with qualitative data: Regime [HIN 1983] and Qualiflex [PAE 1976].
- Converting methods (subjective assessments of relative importance to a set of overall scores or weights by pairwise comparisons): Analytical Hierarchy Process [SAA 1980] with the sub variants REMBRANDT [LOO 1992], MACBETH [BAN 1994].[28]
- Fuzzy MCA methods [CHE 1992].

The most commonly used probabilistic technique is decision trees with utility theory, like the *Subjective Expected Utility model* or SEU-model [SIM 1982]. The decision tree diagrams the paths of possible courses of action. For each path the tree displays the probability for an outcome or event and the end-nodes display the valuation of the payoff of each outcome. Suppose for instance that a researcher has to decide how to fund his research project. He is faced with two possibilities: apply for funding or go to a casino. By assigning probabilities to the different outcomes (funding: 0.20 application accepted, 0.30 application partially accepted, 0.50 application rejected; casino: 0.01 jackpot, 0.99: no jackpot) and values (0.7: funding application fully accepted, 0.4: application partially accepted, 1.0: jackpot), it is possible to calculate that applying for funding is the best alternative[29]:

$$0.2 \times 0.7 + 0.3 \times 0.4 + 0.5 \times 0 > 0.01 \times 1.0 + 0.99 \times 0$$

See Figure 7-1.

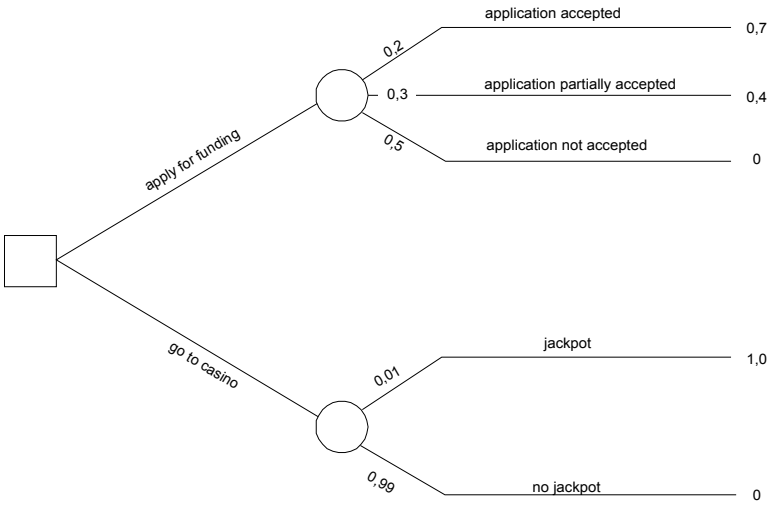

Figure 7-1: Example of a decision tree (SEU-model).

[27] *Option A outranks Option B if there are enough arguments to decide that A is at least as good as B, while there is no overwhelming reason to refute that statement.*
[28] *These methods are primarily used in a single decision-maker context.*
[29] *Note that in theory both options require an initial investment, which should be subtracted fromthe end result.*

Combinations of multi-criteria analysis methods or deterministic statistical techniques and SEU-models or probabilistic statistical techniques have been described as well [KEE 1993].

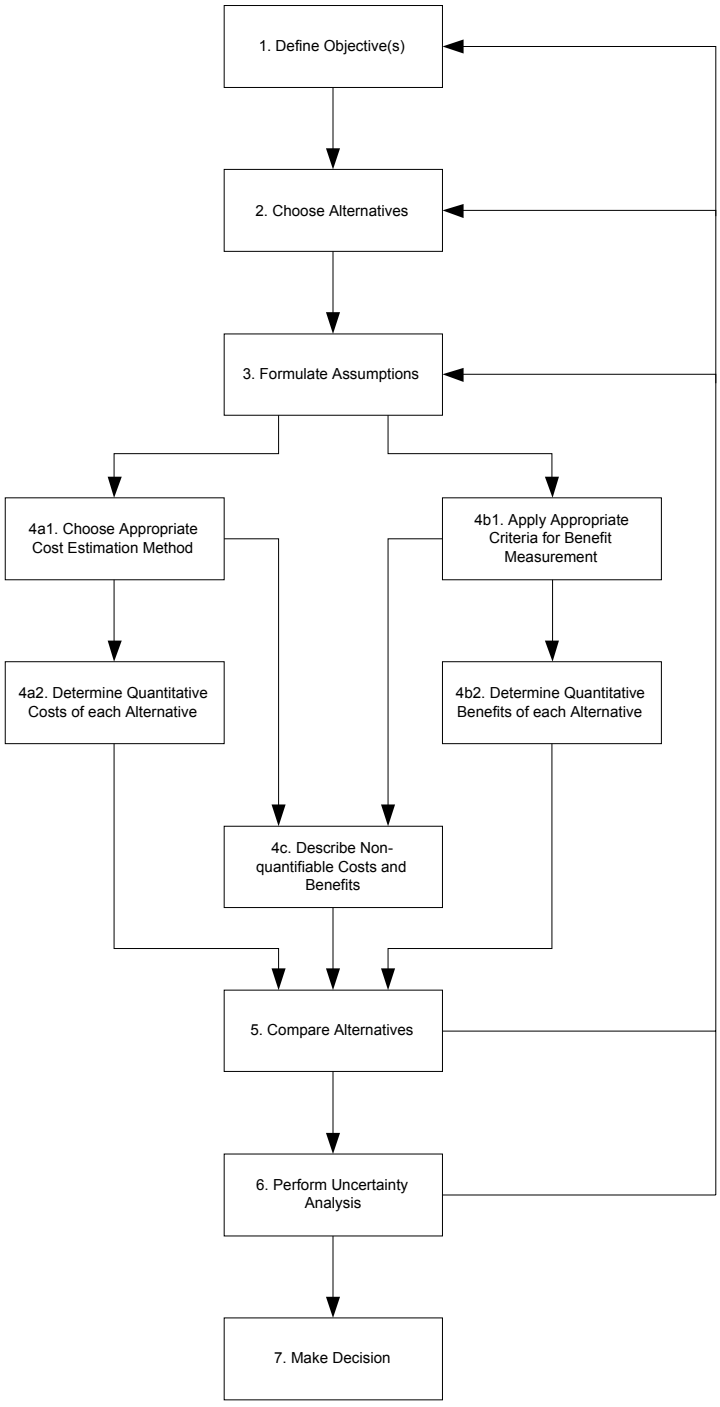

Figure 7-2: General process for economic analysis [DRM 1997]. [30] [31] [32]

[30] *Minor adjustments made here are the jumps back from steps 5 and 6 to steps 1, 2 or 3.*
[31] *Note that '5. Comparing Alternatives' is the phase where statistical techniques like multi-attribute decision models be used.*
[32] *If elements of uncertainty are involved, the economic analysis can be extended with an uncertainty analysis. Available techniques are for instance contingency analysis (to verify that the ranking of alternatives holds up when a relevant change in criteria for evaluating the alternatives is postulated), sensitivity analysis (instead of using expected values for uncertain parameters, several values may be used to see how sensitive the ranking of alternatives is) and "a fortiori" analysis (if a generally accepted intuitive judgment strongly favors one alternative, although this is not revealed in the ranking of the alternatives).*

7.2.2 Framework

In section 2.3 a control system was presented that put the product development activities of a supplier organisation in a broader perspective. Different development steps were defined. Each of them, except for the last one, involved decision-making whether or not to proceed to the next development step by selecting amongst a limited number of alternatives. Finally, it must be decided whether or not to release the software product. It has been argued that this is in fact an investment activity, a review of the business case. When a release decision is an investment activity, it can also be argued that the preceding steps in product development are preliminary release decisions, in which release criteria are defined, deployed and evaluated. Differences are that the final release decision will be the point of no return where the product is transferred from the development phase to the operational phase, and that economic and technical uncertainties existing at the start of product development have been reduced or even eliminated. This model can also be used as a framework to give an overview of economic methods, statistical techniques and mathematical models. The four defined development steps have in common that alternatives are compared and the alternative meeting the defined objective(s) best, will be chosen. In Figure 7-2, a general process is given that might be used (eventually in an adjusted or limited form) during each step.

In the remainder of this section, a further description of the first four development steps is given, with special attention to possible methods, techniques and models that might be used.

Investment proposal
The first step is building the business case for a new product or another version of an existing product [REI 2002]. The central question is: *why build the product?* In this step, the external release criteria are defined in high-level terms. Examples of these criteria could be: functionality, quality, time-to-market, pre-release or development cost, post-release or operational cost (corrective, adaptive and perfective maintenance) and compliance to external standards. Different economic calculation methods may be used here. The Net Present Value or NPV-method is the most widely accepted traditional discounted cash flow (DCF) method. It calculates the return on an investment I by subtracting the operational cost M from the generated assets C, taking into account the discounted value of money after the development T by the risk factor d [ERD 1999]. See Figure 7-3. In formulae:

$$NPV = (C - M) / (1 + d)^T - I \qquad \text{(Net Present Value)}$$

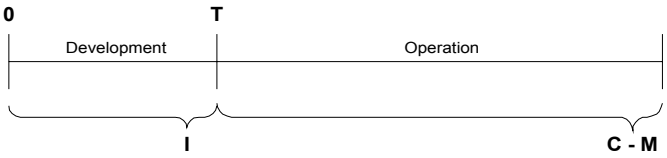

Figure 7-3: Simplified economic model.

During recent years, there has been a tendency to apply option-pricing theory to information technology investments, referred to as the real option (RO) approach ([BOE 2000] and [SUL 1999]).[33] Important reasons for the choice are that the NPV-method is static and does not incorporate management flexibility to stop a project (staged investment or time-to-build option). Further, the NPV-method does not include the possibility to start second-stage projects (build option). However, there is also criticism of the real option approach. It is very complex and still leaves management with the difficult task to estimate input parameters [RIB 1997]. An alternative is to extend NPV with the time-to-build and build option (Figure 7-4). In [RIB 1997] an example is given of extending NPV with decision tree analysis, offering the possibility to incorporate the time-to-build option (combination of an economic method with a statistical technique).

[33] *A general comparison between the traditional DCF methods and the RO approach can be found in [MAN 2000].*

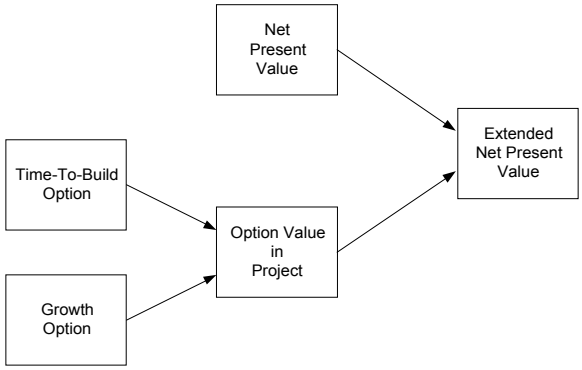

Figure 7-4: Extended Net Present Value with time-to-build and growth option.

Project definition
The second step is defining the boundaries of the project, taking into account both the external release criteria (from the business case) and combining them with the internal release criteria, like compliance to internal standards and additional quality criteria. The central question is: *how to build the right product?* Mathematical models or so-called cost estimation models like COCOMO II [BOE 2001] and SLIM Estimate [PUT 1992] may be used here to make a trade-off between functional product needs, non-functional product needs, lead-time and cost.[34] Different project alternatives may be evaluated with multiple stakeholders using a statistical technique like the Win-Win Negotiation Model [IN 2001]. During the Project Definition phase the business case might be adjusted due to newly gained insights: either the external circumstances have changed (market) or the application of a cost estimation model has revealed new ideas or encountered impossibilities.

Product design
The third step is to evaluate different design or architecture alternatives. The central question is: *how to build the product right?* Important criteria may be both the defined non-functional product needs or quality criteria (such as reliability, maintainability, see [ISO 1991]) and the expected cost. Supporting methods are for instance ATAM [KAZ 1998], SAAM [DeS 1995] and CBAM ([ASU 2000] and [ASU 2001]). These are scenario-based evaluation methods.[35] During the Product Design phase the business case may be adjusted again: either the external circumstances have changed (market) or the application of an evaluation method revealed new ideas or encountered impossibilities.

Product release
After the product has been implemented, tests will be started to test to which degree the functional and non-functional product needs have been implemented correctly. The central question is: *when to stop building the product?* At the same time, relevant information is gathered to support the final release decision. No supporting methods have been found other than statistical techniques like defect prediction models to make quantitative or qualitative statements about reliability ([CHI 1992], [LYU 1995], [AGE 2002]) and assessment models [BOS 2000b] to quantify maintainability. With respect to reliability, software defect prediction models have been developed since the seventies. Research in the area of reliability engineering has been done for instance by Musa [MUS 1975] and Lyu [LYU 1995]. Fenton and Neil have studied the most widely accepted models. They identified severe problems such as [FEN 1999]:

- There is no distinction made in different notions of 'defect'.[36]
- Statistical methods are often flawed.
- Product size is wrongly assumed to be a causal factor for defects.
- Obvious causal factors are not taken into account.
- Black box models hide crucial assumptions.
- The models cannot handle uncertainty.

[34] *A comprehensive overview and comparison of available models can be found in [BRI 2000].*
[35] *A comprehensive overview of five different methods can be found in [ION 2002]. Other useful references are [CLE 1999] and [BOS 2000a].*
[36] *Note that in this study the terms 'failure' and 'fault' are used. See Glossary for the definitions. For failures distinction is made between the following categories: 'catastrophic', 'critical', 'marginal', and 'minor' conform the definitions in [MIL 1984].*

They conclude that as a result these models provide little support for determining reliability of a software product. Their study also showed that the number of pre-release faults is not a good indicator of the number of post-release faults. The problem is that many software suppliers use the pre-release fault counts as a measure for the number of post-release faults, e.g. the reliability of the released product. These research outcomes combined with a further investigation led to the conclusion by Fenton and others that Bayesian nets offer a model that takes into account the crucial concepts missing from classical approaches [FEN 1998]. A Bayesian net is a graphical network (see Figure 7-5) together with an associated set of probability tables. The nodes in the net represent uncertain variables and the arcs in the net represent causal/relevance relationships between the variables. Classical prediction methods do not take these relationships into account, but focus on correlation between variables (for instance size and defects). The probability tables for each node provide the probabilities of each state of the variable of that node. For nodes without parents these are just the marginal probabilities while for nodes with parents these are conditional probabilities for each combination of parent state values [AGE 2002]. Once a Bayesian net has been set up, evidence about variables (as soon as available) can be entered. All the probabilities will be updated accordingly, offering valuable information concerning variables we are interested in predicting.

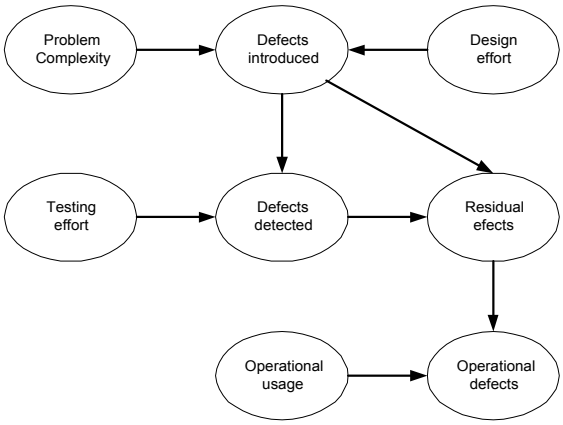

Figure 7-5: Example of Bayesian Net for defects [AGE 2002].

In Figure 7-6 an overview is given of the entire framework with examples of supporting methods, models and techniques.

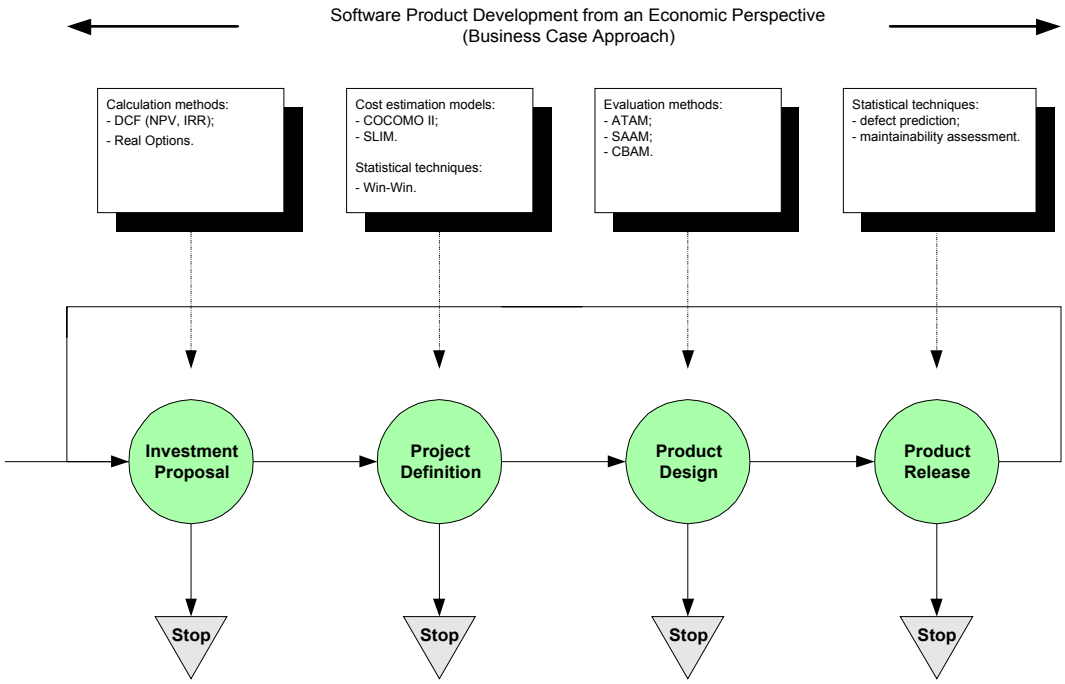

Figure 7-6: Framework for methods, techniques and models during product development.

7.3 Behavioural Perspective

The criticism on utility-based or in this case economic-based models is extensive and diverse. In this section some possible effects appearing from the disciplines Psychology, Sociology and Social Psychology will be discussed. The discipline Psychology will not be taken into account in the remainder of this study. It will however be briefly explained how psychological forces influence the behaviour of individuals. This is considered important for two reasons. In the first place, a broad range of social values merges with the decision-maker's personal values [ALD 1975]. In the second place the collective behaviour of a group is a direct consequence of individual decision procedures with the addition of a process for resolving conflict [CLA 1966]. Focus will however be on the effects emerging from the disciplines Sociology and Social Psychology as they influence the behaviour of groups.

7.3.1 Individual Behaviour (psychology)

If is very difficult if not impossible for decision-makers to escape the diverse psychological forces that influence their individual behaviour. These forces lead to cognitive limitations. Examples are:

- *Cognitive syndromes* [STE 1974]. A decision-maker is faced with bounded rationality, because he thinks in certain patterns. Distinction can for instance be made into *grooved thinking* (routine), *uncommitted thinking* (caused by inconsistent information causing that different alternatives remain acceptable) and *theoretical thinking* (preference for a specific choice as a result of conviction and ideology rather than rationality).
- *Motivation of decision-makers* [SIM 1982], leading to problem avoidance. A decision-maker searches for a satisfying solution and not by default the best solution. He will be more strongly influenced by the current advantages and disadvantages (short term) rather than the future ones (long term).
- *Limited cognitive capabilities of decision-makers* [SIM 1982], leading to simplification. A decision-maker simplifies reality, leaves out information and prefers simple rules of thumb as a consequence of limited cognitive capabilities. Reasons are for instance that the decision-maker has available limited, unreliable or even too much information or that the search for acceptable alternatives is felt to be too much time-consuming and cost consuming.
- *Incrementalism* [BRA 1970]. Braybrooke and Lindblom describe the strategy of disjointed incrementalism and address eight issues undermining the idea that the judgment of a situation is absolute. Instead they claim that a decision-maker judges a situation in a relative way, in other words they take into account the additional cost and benefits of the current situation and not the total cost and benefits. This leads to two important consequences [HUI 1994, p. 121]:
    - The valuation of an alternative depends on the current situation. The same alternative might be judged as more attractive if the current situation is unfavourable. This is the core of the theory of *framing* and *heuristics* ([KAH 1982], [TVE 1981]).
    - The fact that only additional cost and benefits are taken into account might lead to *entrapment* [HIL 1979]. A situation may be created in which for instance the total cost exceed acceptable limits.
- *Values*. The values of decision-makers do not have the ideal properties like absolute, relevant, stable, consistent, precise, and exogenous [MAR 1978]. England describes a personal value system as *a relatively permanent perceptual framework, which shapes and influences the general nature of an individual's behaviour* [ENG 1967]. Value systems have the following general qualities [ENG 1967, p. 54]:
    - They affect the perception of situations and problems.
    - They affect the entire process of choice.
    - They affect personal relationships.
    - They affect the perception of individual and organisational achievement and success.
    - They set the limits for ethical behaviour.
    - They affect the acceptance of or resistance to organisation pressures and goals.

Summarized, when looking at individual behaviour of stakeholders in a decision-making process the criticism on an economic approach is two fold. First of all decision-makers may not use a rational

decision model, because there are reasons to make the decision without using the model. In the second place the assignment of values and probabilities is influenced by numerous factors, possibly leading to a situation where a cost/benefit calculation is not performed on objective grounds.

7.3.2 Group Behaviour (sociology and social psychology)

There are more factors that influence decision-making. Berghout describes for instance [BER 1997, pp. 35-42]:

- *Organisational problems*. Keunink and Epping make a distinction between three types of decisions [KEU 1979, p. 29]:
  - *Strategic decisions*, concerning the organisation and its external environment.
  - *Organisational decisions,* concerning the internal structure of the organisation.
  - *Operational decisions,* concerning the optimisation of assets in the organisation.

  They associate these decisions with three major organisational problems: external co-ordination, internal co-ordination and structuring [KEU 1979, p. 8].
- *Political aspects* [MUL 1979]. Mulder distinguishes four bases for power:
  - *Sanction power*: a person is influenced by the idea that he may be either rewarded or punished depending on his choice.
  - *Legitimate power*: a person obeys because he thinks that is what is expected.
  - *Referent power*: another person is taken as an example or role model to be resembled.
  - *Expert power*: greater knowledge or skills are assumed to be proportional to the level of power.

These additional factors are of interest as well as looking at the decision whether or not to release a software product. They surface in the decision-making process when the group of stakeholders tries to make a collective decision.

From the conducted case studies it follows that the stakeholders try to find consensus about whether or not to release the product. In each case study the stakeholders involved were working in the same organisation. This may lead to the conclusion that they strive towards the same outcome. In that case they would simply turn the preferred outcome into a decision and act accordingly. However, as argued in section 6.4, the stakeholders involved in the decision-making process will have different positions and different preferences with respect to the outcome (group behaviour). Harrison classifies decision-making groups in three primary types [HAR 1987, p. 237]:

- *Interacting group technique*, characterized by group discussion and pool judgments.
- *Nominal group technique*, characterized by a recorded round-robin presentation of individual opinions and a pooled outcome of individual notes.
- *Delphi technique*, characterized by getting a final opinion from a group through sequential surveys where the participants do not meet each other.

In Figure 7-7 an overview of these types is given in relation to group decision criteria, group situational characteristics and group membership [HAR 1987, p. 240]. The column *Release decision* has been added, describing the characteristics of a release decision. It follows that a release decision matches well with the *Interacting Group* type.

The Interacting Group type means that discussions are used to decide whether or not to release the product. In each case study the stakeholders involved were working in the same organisation (co-workers), sometimes representatives from the end-users were present as well. This may lead to the conclusion that they strive toward the same outcome. In that case they would simply turn the preferred outcome into a decision and act accordingly. However, as argued in section 6.4, the stakeholders involved in the decision-making process will have different positions and different preferences with respect to the outcome (group behaviour).

Profile Variables	Release decision	Interacting Group	Nominal Group	Delphi Group
1. Group decision criteria a. Quality b. Acceptance c. Originality	 high high moderate	 ***Moderate to high*** ***Moderate to high*** ***Low to moderate***	 Moderate Moderate ***Moderate***	 Low or moderate Low to moderate ***Moderate to high***
2. Group situational characteristics a. Availability of expertise b. Span of the decision c. Conflict within the group	 moderate broad low	 ***Low to moderate*** ***Intermediate to broad*** Moderate to high	 ***Moderate*** Intermediate ***Low to moderate***	 Moderate to high Narrow to intermediate ***Low***
3. Group membership a. Experts b. Representatives c. Coworkers	 occasionally frequentlly usually	 ***Occasionally*** ***Frequently*** ***Usually***	 Frequently ***Occasionally*** ***Frequently***	 Usually Seldom Occasionally

Figure 7-7: Conceptualised profiles of decision-making groups [HAR 1987, p. 240].

Stokman et al. describe three elements that determine the outcome of a decision: the *positions* of the stakeholders, the *salience* of the stakeholders (i.e. the degree to which they are interested in each issue) and the *capabilities* of the stakeholders [STO 2000]. The process of decision-making can be described as the efforts of the stakeholders to realise an outcome of the decision that is as close as possible to their own position. In other words: how can the positions of other stakeholders be moved towards one's own? Stokman et al. distinguish three main processes through which a stakeholder changes his position [STO 2000]:

- *Management of meaning processes and strategies*: the stakeholder receives convincing information implying that another position reflects his incentive structure better. Important aspects here are:
  - New information is generally more accepted in earlier stages of the decision-making than in the later ones;
  - A substantial amount of trust in the provider of the information increases the likelihood that information is accepted as relevant and reliable.
- *Challenge processes and strategies*: other stakeholders challenge the position of the stakeholder and he feels more or less forced to change his position. This is influenced by:
  - One's own position at the beginning of the decision-making process.
  - The leverage one shows to others.
  - Explicit evaluation of the likelihood of success.
- *Exchange processes and strategies*: a stakeholder is prepared to take another position on an issue in exchange for a favourable (for him) move by another stakeholder on another issue. Three elements are considered of importance here:
  - The selection of the issues one wants to include in the exchange process.
  - The change one incorporates into one's own positions.
  - One's prioritisation of the issues.

For release decisions it will be of special interest to elaborate on the management of meaning process and strategies. It is assumed here that the application of a framework as described in the previous section will contribute to an increase of the quality of information, both in completeness and reliability.

7.4 Adoption Theory

It is assumed here that the theories of innovation diffusion can be applied to the adoption of the methods, techniques and models as described in section 7.2, but further research will be needed. Rogers has made an overview of the most significant findings and compelling theories related to diffusion [ROG 1995]. Four of the theories discussed by Rogers are among the most widely used theories of diffusion:

- Innovation Decision Process;
- Individual Innovativeness;
- Rate of Adoption;
- Perceived Attributes.

They will be briefly presented in this section as well as some general remarks about the adoption process.

7.4.1 Innovation Decision Process

The Innovation Decision Process states that diffusion is a process that occurs over time and can be seen as having five distinct stages. The stages in the process are:

- Exposure to its existence, and understanding of its functions (*Knowledge*).
- The forming of a favourable attitude to it (*Persuasion*).
- Commitment to its adoption (*Decision*).
- Putting it to use (*Implementation*).
- Reinforcement based on positive outcomes from it (*Confirmation*).

According to this theory, potential adopters of an innovation must learn about the innovation, be persuaded as to the merits of the innovation, decide to adopt, implement the innovation, and confirm (reaffirm or reject) the decision to adopt the innovation. While Sachs correctly concludes that many other important theories of innovation diffusion are overlooked [SAC 1993], the Innovation Decision Process theory remains among the most useful and well known.

7.4.2 Individual Innovativeness

The Individual Innovativeness theory states individuals who are predisposed to being innovative will adopt an innovation earlier than those who are less predisposed. Figure 7-8 shows the bell shaped distribution of Individual Innovativeness and the percentage of potential adapters theorized to fall into each category.[37] On the left extreme of the distribution are the Innovators. Innovators are the risk takers and pioneers who adopt an innovation very early in the diffusion process. On the right extreme are the Laggards who resist adopting an innovation until rather late in the diffusion process (if ever).

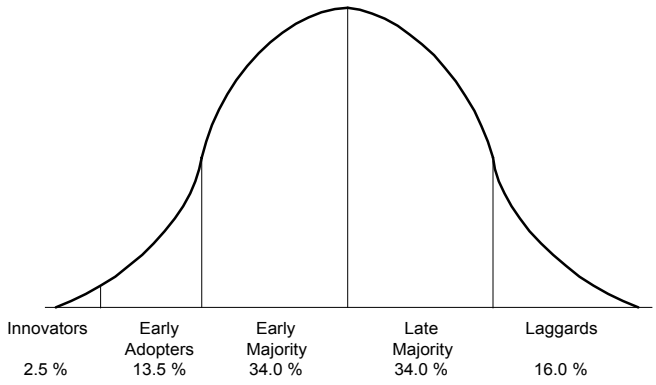

Figure 7-8: Curve showing individual innovativeness and percentages within each category.

7.4.3 Rate of Adoption

The third widely used diffusion theory is the theory of Rate of Adoption. Rate of Adoption theory states that innovations are diffused over time in a pattern that resembles an S-shaped curve. Rate of Adoption theorizes that an innovation goes through a period of slow, gradual growth before experiencing a period of relatively dramatic and rapid growth. An example of how rate of adoption might typically be represented by an S-curve is shown in Figure 7-9. The theory also states that following the period of rapid growth, the innovation's rate of adoption will gradually stabilize and eventually decline.

[37] *Note the resemblance of this figure with Figure 2-13in section 2-6.*

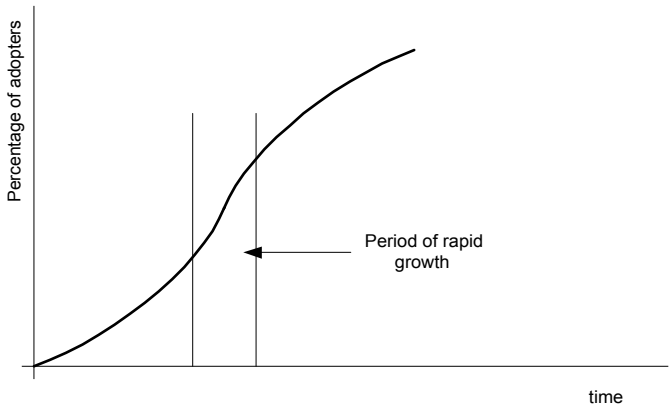

Figure 7-9: Curve representing rate of adoption of an innovation over time.

7.4.4 Perceived Attributes

The Theory of Perceived Attributes states that potential adopters judge an innovation based on their perceptions in regard to five attributes of the innovation. The theory holds that an innovation will experience an increased rate of diffusion if potential adopters perceive that the innovation:

- Can be tried on a limited basis before adoption (*Triability*).
- Offers observable results (*Observability*).
- Has an advantage relative to other innovations or the status quo (*Relative Advantage*).
- Is not overly complex (*Complexity*).
- Is compatible with existing practices and values (*Compatibility*).

7.4.5 Adoption Process

Adoption decisions may be *optional* (where the person or organisation has a real opportunity to adopt or reject the idea), *collective* (where a decision is reached by consensus among the stakeholders), or *authority-based* (where a decision is imposed by another person or organisation which possesses requisite power, status or expertise).
Important roles in the adoption process include:

- *Opinion leaders*, who have frequent informal influence over the behaviour of others.
- *Change agents*, who positively influence innovation decisions, by mediating between the change agency and the relevant social system. Their functions are:
  - To develop a need for change on the part of the client;
  - To establish an information-exchange relationship;
  - To diagnose the client problems;
  - To create intent to change in the client;
  - To translate this intent into action;
  - To stabilise adoption and prevent discontinuance;
  - To shift the client from reliance on the change agent to self-reliance.
- *Change aides,* who complement the change agent, by having more intensive contact with clients, and who have less competence credibility but more safety or trustworthiness credibility.

7.5 Preconditions

In the next phase the Conceptual Method will be specified. The following preconditions will be taken into account:

- *Organisational characteristics*. Documented policies and processes are in place. If this is not the case, it will be impossible to obtain sufficient commitment for a more formal approach to software releasing. Instead, such organisations should give priority to institutionalise their development process.

- *Market characteristics*. The trade-off decision between lead-time, functional product needs, reliability, pre-release cost (budget) and post-release cost (maintenance) is both important and complex. As a consequence, the method will be broad in the sense that its application will be possible both in commercial organisations developing software for external customers and organisations developing software to support internal processes.
- *Product characteristics*. The developed product must be the first version of a new product or a major revision of an existing product and be of strategic importance to an organisation. This means that the method will apply to Category II decisions for which the associated risks are considered to be higher than for Category I decisions.

These preconditions correspond with the criteria that were used to select the organisations for the case studies, extended with the precondition about product characteristics. Specifying a method for both Category I and Category II decisions would broaden the scope of the method too much. Focussing on Category II decisions only will facilitate the possibility to validate the method accurately afterwards and draw useful conclusions.

7.6 Next Steps

In this report, the initial central research question has been adjusted using the results of the exploratory case studies. This adjustment has lead to an approach to making release decisions for software products from two different perspectives: an economic perspective and a behavioural perspective.

The next steps in the study are closely related to the sub questions raised in the study (see section 6.4).

Regarding the economic perspective the following steps will be undertaken:

- The framework as discussed in section 7.2 will be further developed. An investigation will be made which economic methods, statistical techniques and mathematical models can be used in each development stage and how they interrelate to each other.
- Interesting aspect to investigate as well is the question what possible reasons exist for using or not using the economic methods, statistical techniques and mathematical models. What are specific criteria to an organisation and its group of decision-makers to adopt them? The theories of innovation diffusion will be further investigated. This will however be done in a limited way. The main objective here is to derive possibly additional preconditions for the application of the overall method to be specified.

Regarding the behavioural perspective the following steps will be undertaken:

- It will be investigated how the method must deal with the opposed effects from the other disciplines Sociology and Social Psychology, influencing group behaviour in decision-making. How can these effects be recognized? How can the negative consequences be reduced or eliminated? The theory of Stokman et al. will be used as the main reference [STO 2000].

These steps will lead to the specification of a method as an answer to the central research question. Once the method has been specified, it will be validated in practice.

7.7 Finally: Do the Numbers Really Matter?

The subtitle of this report is *"Do the numbers really matter?"* Seen from a quantitative perspective they do matter. In most cases, organisations will only invest in software products to increase their business results. This is both true for organisations selling their developed products to external customers and for organisations investing in information technology to support their internal processes. However, finding a satisfying moment to release software products from a purely quantitative or even financial perspective is found to be difficult if not impossible. There are two reasons for this. In the first place, the available information is limited as organisations try to reach the point of optimality. Beyond this point, obtaining additional information would lead to diminishing returns. Secondly, looking from a behavioural perspective the effects of individual and group behaviour play a role due to cognitive limitations and due

to the fact that it inevitable that the stakeholders in the decision-making process will have different positions and different preferences with respect to the outcome.

Based on this study, the most important characteristics of a release decision are defined as follows:

> *A software release decision is the act of choice function in a managerial decision-making process where a software product is transferred from the development phase to the operational phase. This is either a routine or nonroutine decision depending on the phase in the product's lifecycle and the strategic importance of the product to the organisation. The available information to compare and evaluate alternatives is limited in both quantitative and qualitative terms. The stakeholders involved being the decision-makers have in general different positions and preferences with respect to the outcome and will search for a satisfying outcome.*

The challenge in the next phase of this study will be to specify a method that supports organisations to determine their specific point of optimality at which the numbers do matter and that reduces the negative consequences of group behaviour to acceptable limits.

References

[AGE 2002] *"Software Metrics and Risks"*, Technical Report, Agena Limited, 11 February.

[ALD 1975] *"A Managerial Framework for Social Decision Making"*, R.J.Aldag, D.W.Jackson Jr., MSU Business Topics, 23 (spring), pp. 33-40.

[ALL 1971] *"Essence of Decision: Explaining the Cuba Missile Crisis"*, G.T.Allison, Boston: Little, Brown, pp. 29-30.

[ASU 2000] *"An Architectural Approach to Software Cost Modeling"*, J.Asundi et al., Second International Workshop on Economics-driven Software Engineering Research, Limerick, (Ireland).

[ASU 2001] *"A Foundation for the Economic Analysis of Software Architectures"*, J.Asundi, R.Kazman, Third International Workshop on Economics-driven Software Engineering Research, Toronto (Canada).

[BAN 1994] *"MACBETH – an interactive path towards the construction of cardinal value functions"*, C.A. Bana e Costa, J.C.Vansnick, International transactions in operational Research, 1 (4). pp. 489-500.

[BAY 1999] *"Software Release Methodology"*, M.Bayes, Prentice Hall.

[BER 1997] *"Evaluation of information system proposals: design of a decision support method"*, E.W.Berghout, doctoral dissertation, Delft University of Technology.

[BOE 1978] *"Characteristics of Software Quality"*, B.W.Boehm, J.R.Brown, J.R.Kaspar, TRW Series of Software Technology, Amsterdam, North Holland.

[BOE 2000] *"Software Economics: A Roadmap"*, B.W.Boehm, K.J.Sullivan, ACM Press.

[BOE 2001] *"Software Cost Estimation with COCOMO II"*, B.W.Boehm et al., Prentice-Hall.

[BOS 1988] *"Beleidseffectiviteit en case-studies: een vergelijking van verschillende onderzoeksonderwerpen"*, A.F.Boskma, M.Herweyer, Beleidswetenschap, No. 1, pp. 52-69.

[BOS 2000a] *"Design and Use of Software Architectures"*, J.Bosch, Addison-Wesley.

[BOS 2000b] *"Assessing Optimal Software Architecture Maintainability"*, J.Bosch et al., fifth European Conference on Software Maintainability and Reengineering.

[BRA 1970] *"A Strategy of Decision: Policy Evaluation as a Social Process"*, D.Braybrooke, C.E.Lindblom, New Yowk: Free Press.

[BRI 2000] *"Resource Estimation in Software Engineering"*, L.C.Briand, I.Wieczorek, International Software Engineering Research Network, Technical report ISERN 00-05.

[BUS 1999] *"Software Hell"*, Business Week, December, pp. 104-118.

[BUT 1990] *"Getting value from information technology"*, C.Butler, Research Report 75, London (UK).

[CAL 1979] *"A Discriminant Model for Identifying Scenarios of Industrial New Product Failure"*, R.J.Calantone, R.G.Cooper, Journal of the Academy of Marketing Science, vol. 7, no. 3, pp. 163-183.

[CCT 2002] *"Managing Successful Projects with PRINCE2 (PRINCE Guidance)"*, Central Computer and Telecommunications Agency.

[CHE 1992] *"Fuzzy Multiple Attribute Decision Making: Methods and Applications"*, S.J.Chen, C.L.Hwang, Lecture Notes in Economics and Mathematical Systems, No. 375, Springer Verlag, Berlin.

[CHI 1992] *"Orthogonal Defect Classification – A Concept for In-Process Measurements"* R.Chillarege et al., IEEE Transactions on Software Engineering, Vol.18, No.11.

[CLA 1966] *"Toward a Theory of Group Decision Behaviour"*, G.P.E.Clarkson, F.D.Tuggle, Behavioral Science, January edition, pp. 33-42.

[CLE 2002] *"Evaluating Software Architectures"*, P.Clements et al., Addison-Wesley, ISBN 0-201-70482-X.

[COS 1963] *"Psychology in Administration: A Research Orientation"*, T.W.Costello, S.S.Zalkind, Prentice-Hall.

[COT 2000] *"Real options and competitive dynamics in software product release"*, T.Cottrell, Second International Workshop on Economics-driven Software Engineering Research, Limerick (Ireland).

[DEN 2001] *"The Profession of IT: Chrossing the Chasm"*, P.J.Denning, Communications of the ACM, Vol. 44, No. 4, pp. 21-25.

[DeS 1995] *"Using SAAM: An Experience Report"* M.DeSimone, R.Kazman, Proceedings of CASCOM '95, Toronto (Canada), pp.251-261.

[DRM 1997] *"Economic Analysis Handbook"*, Defense Resources Management Institute, 2nd Edition, Naval Postgraduate School, Monterey (California).

[DRO 1996] *"Cornering the Chimera"*, R.G.Dromey, IEEE Software, Vol. 13, No. 1, pp. 33-43.

[EDW 1994] *"SMARTS and SMARTER: improved simple methods for multiattribute utility measurement"*, W.Edwards, F.H.Barron, Organizational Behavior and Human Decision Processes, Vol. 60, pp. 306-325.

[ENG 1967] *"Personal Value Systems of American Managers"*, Academy of Management Journal, pp. 53-68.

[ERD 1999] *"Comparative evaluation of software development strategies based on Net Present Value"*, H.Erdogmus, First International Workshop on Economics-driven Software Engineering Research, Toronto (Canada).

[FEN 1998] *"Assessing Dependability of Safety Critical Systems using Diverse Evidence"*, N.Fenton et al., IEE Proceedings Software Engineering, 145(1), pp. 35-39.

[FEN 1999] *"A Critique of Software Defect Prediction Research"*, N.Fenton and M.Neil, IEEE Transactions on Software Engineering, Vol. 25, No. 5.

[GLA 1998] *"Software Runaways: Monumental Software Disasters"*, R.L.Glass, Prentice-Hall.

[GRA 1992] *"Practical Software Metrics for Project Management and Process Improvement"*, R.B.Grady, Prentice Hall, pp. 22-24.

[HAR 1987] *"The managerial decision-making process"*, E.F.Harrison, Houghton Mifflin Company, Boston (MA), Third Edition.

[HAR 2001] *"Managing increasing returns"*, E. den Hartigh, F.Langerak, European Management Journal, Vol. 19, pp. 370-378.

[HIL 1979] *"Making Decisions: A Multidisciplinary Introduction"*, P.H. Hill, et al., Addison-Wesley Publishing Company, Inc.

[HIN 1983] *"The Regime method: a new multi-criteria technique"*, E.Hinloopen et al., P. Hansen (ed.) Essays and Surveys on Multiple Criteria Decision Making, Springer Verlag, Berlin.

[HOG 1980] *"Judgment and Choice"*, R.M. Hogarth, pp. 53-74, Wiley.

[HOL 2002] *"Improving Performance in Business Development"*, J.Hollander, doctoral dissertation, University of Groningen, The Netherlands.

[HUI 1994] *"Reader Besluitvormingstheorie"*, F.D. Huizenga, vierde herziene druk, Faculteit der Sociaal-Culturele Wetenschappen, Vakgroep Politocologie en Bestuurskunde, VU Amsterdam.

[HWA 1981] *"Multi Attribute Decision Making: Methods and Applications"*, C.L.Hwang, K.Yoon, Springer-Verlag, New York (NY).

[IEE 1990] *"IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries",* Institute of Electrical and Electronics Engineers, New York, NY.

[IN 2001] *"A Requirements Negotiation Model Based on Multi-Criteria Analysis"*, H.In et al., International Symposium on Requirements Engineering, Toronto (Canada).

[ION 2002] *"Scenario-Based Software Architecture Evaluation Methods: An Overview"*, M.T.Ionita et al., Proceedings of the International Conference on Software Engineering, Orlando (FA).

[ISO 1991] *"ISO/IEC 9126: Information Technology - Software Product Evaluation - Quality characteristics and guidelines for their use"*, ISO.

[ISO 1999] *"ISO/IEC 14598-1. Information Technology - Software Product Evaluation, Part 1 – General overview"*, ISO.

[KAH 1982] *"Judgment under Uncertainty: Heuristics and Biases"*, D.Kahneman, P.Slovic, A.Tversky, New York, Cambridge University Press.

[KAZ 1998] *"The Architectural Trade-off Analysis Method"*, R.Kazman et al., Software Engineering Institute, CMU/SEI-98-TR-008.

[KEE 1993] *"Decisions with Multiple Objectives: Preferences and Value Trade-offs"*, R.L.Keeney, H.Raiffa, Cambridge University Press.

[KEU 1979] *"Management en Organisatie"*, D.Keuning, D.J.Eppink, Stenfert Kroese, Leiden, ISBN 90-207-0879-1.

[KIT 1996] *"Software Quality: The Elusive Target"*, B.Kitchenham, Shari L.Pfleeger, IEEE Software, Vol. 13, No. 1, pp. 12-21.

[LEE 1990] *"Organisaties: Management, Analyse, Ontwerp en Verandering: een systeemvisie"*, A.C.J. de Leeuw, Van Gorcum, Assen/Maastricht, 4th edition (in Dutch).

[LEE 1994] *"Besturen van Veranderingsprocessen: Fundamenteel en Praktijkgericht Management van Organisatieveranderingen"*, A.C.J. de Leeuw, Van Gorcum, Assen, pp. 69-74 (in Dutch).

[LEV 1993] *"An Investigation of the Therac-25 Accidents"*, N.G.Leveson, C.S.Turner, IEEE Computer, Vol. 26, No. 7, pp. 18-41.

[LEV 1994] *"Safeware: System Safety and Computers"*, N.G.Leveson, Addision-Wesley.

[LOO 1992] *"The REMBRANDT System for Multi-criteria Decision Analysis via Pairwise Comparisons or Direct Rating"*, F.A.Lootsma, Report 92-05, Faculty of Technical Mathematics and Informatics, Delft University of Technology, The Netherlands.

[LYU 1995] *"Handbook of Software Reliability Engineering"*, M.R.Lyu, McGraw-Hill.

[McC 1977] *"Factors in Software Quality"*, J.A.McCall et al., RADC TR-77-369, US Rome Air Development Center Reports.

[MAI 1984] *"A Study of Success and Failures in Product Innovation: The Case of the U.S. Elctronics Industry"*, M.A.Maidique, B.J.Zirger, IEEE Transactions on Engineering Management, Vol. 31, no. 4 (November), pp. 192-203.

[MAN 2000] *"Project Valuation: Problem Areas, Theory and Practice"*, A.Mandron, in The Current State of Business Disciplines, Vol. 3, pp. 997-1017.

[MAR 1978] *"Bounded Rationality, Ambiquity, and the Engineering of Choice"*, J.G.March, Bell Journal of Economics 9, pp. 587-608.

[MAR 1979] *"Ambiquity and Coice in Organizations"*, J.G.March, J.P.Olsen, 2nd Edition, Universitetsforlaget (Norway).

[MES 2001] *"Industrial and Economic Properties of Software: Technology, Processes and Value"*, D.G.Messerschmitt, C.Szyperski, Microsoft Research, MSR-TR-2001-11.

[MIL 1984] *"Procedures for Performing a Failure Mode Effects and Criticality Analysis"*, MIL-STD-1629A, Department of Defense, Washington.

[MOO 1995] *"Crossing the Chasm"*, G.Moore, Harperbusiness, New York.

[MUL 1979] *"Omgaan met macht: ons gedrag met elkaar en tegen elkaar"*, M.Mulder, Elsevier, Amsterdam, Third Edition.

[MUS 1975] *"A theory of software reliability and its application"*, J.D.Musa, IEEE Transactions on Software Engineering, SE-1, pp. 312-327.

[PAE 1976] *"Qualitative multiple criteria analysis, environmental protection and multiregional development"*, J.H.Paelinck, Papers of the Regional Science Association, 36, pp. 59-74.

[PAR 1997] *"Designing Software for Ease of Extension and Contraction"*, D.L.Parnas, IEEE Transactions on Software Engineering, March, pp. 128-137.

[POR 1980] *"Competitive Strategy"*, M.E.Porter, New York: Free Press.

[PUT 1992] *"Measures for Excellence: Reliable Software On Time Within Budget"*, L.H.Putnam, W.Myers, Yourdon Press Computing Series.

[REI 2002] *"Making the Software Business Case"*, D.Reifer, Addison-Wesley.

[RIB 1997] *"Option pricing for IT valuation: a dead end"*, P.M.A.Ribbers et al., in E.W.Berghout, & D.S.J.Remeny, (Eds.), Evaluation of Information Technology, (pp. 67-75) Delft University Press.

[ROG 1995] *"Diffusion of Innovations"*, E.M.Rogers, 4th Edition, New York: The Free Press.

[ROI 1996] *"Software Quality in Consumer Electronics Products"*, J.H.Rooijmans et al., IEEE Software, January.

[ROT 1974] *"SAPPHO Updated – Project SAPPHO Phase II"*, R.Rothwell et al., Research Policy, pp. 258-291.

[ROY 1991] *"The outranking approach and the foundations of ELECTRE methods"*, B.Roy, Theory and Decision, Vol. 31, pp. 49-73.

[RTI 2002] *"The Economic Impacts of Inadequate Infrastructure for Software Testing"*, Planning Report 02-3, Prepared by RTI for National Institute of Standards and Technology, U.S. Department of Commerce.

[SAA 1980] *"The Analytic Hierarchy Process"*,T.L.Saaty, John Wiley, New York.

[SAC 1993] *"The Diffusion of Innovations: The Overlooked Literature"*, S.G.Sachs, Association for Educational Communications and Technology, New Orleans, LA.

[SAS 2002] *"Reviews, waarom en hoe?"*, J.A.Sassenburg, Informatie, October, pp. 16-21 (in Dutch).

[SAS 2003] *"When can the software be released?"*, J.A.Sassenburg, Proceedings of the European SEPG, London (UK).

[SAW 1999] *"Technology Marketing"*, M.Sawhney, Lecture Section 8: Managing New Offering Realization, Kellogg Graduate School of Management, Northwestern University (USA).

[SEI 1995] *"The Capability Maturity Model: Guidelines for Improving the Software Process"*, Addison-Wesley.

[SEI 2002] *"Process Maturity Profile of the Software Community, 2001 Year End Update"*, website www.sei.cmu.edu, Software Engineering Institute.

[SIM 1982] *"Models of Bounded Rationality"*, H.Simon, Vol. 2, Cambridge, MIT Press.

[STA 1995] *"Study on project successes and failures"*, Standish Group Report.

[STA 1998] *"Chaos Report"*, Standish Group Report.

[STE 1974] *"The Cybernetic Theory of Decision: New Dimensions of Political Analysis"*, J.D.Steinbruner, Princeton University Press.

[STO 2000] *"Strategic Decision Making"*, F.N.Stokman et al., Advances in Group Processes 17, pp. 131-153.

[SUL 1999] *"Software Design as an Investment Activity: A Real Options Perspective"*, K.J.Sullivan et al., Real Options and Business Strategy: Applications to Decision Making, L.Trigeorgis, ed., (London, England: Risk Books), pp. 215-261.

[TRI 2000] *"Multi-Criteria Decision Making Methods: A Comparative Study*", E.Triantaphyllou, Kluwer Academic Publishers.

[TRU 1966] *"Some Factors Involved in Determining Total Decision Success"*, S.G.Trull, Management Science, B-270-B-280.

[TUR 1990] *"SDM, System Development Methodology"*, W.S.Turner et al., Cap Gemini Publishing (in Dutch).

[TVE 1981] *"The framing of Decisions and the Psychology of Choice"*, A.Tversky, D.Kahneman, Science, 21, pp. 453-458.

[VRI 1992] *"Stepwise multi-criteria evaluation"*, M.S. de Vries, uit "Quality and Quantity: the European Journal of Methodology", Kluwer Academic Publishers, Amsterdam, Vol. 26.

[YIN 1994] *"Case Study Research: Design and Methods"*, Robert K.Yin, Sage Publications, 1994.

Glossary

availability *– probability that a product will operate without* ***failure*** *under given conditions for a given time interval*
(in formulae: availability = ***MTBF*** */ (****MTBF*** *+* ***MTTR****))*

decision *- a moment in an ongoing* ***process*** *of evaluating alternatives for meeting an objective, at which expectations about a particular course of action impel the decision-maker(s) to select that course of action most likely to result in attaining the objective (based on [HAR 1987, p. 5])*

definition of release criteria *– the act of defining* ***release criteria***

deployment of release criteria *– the act of deploying* ***release criteria*** *to lower-level process attributes and product attributes*

evaluation of release criteria *– the act of obtaining measured values for* ***release criteria***

failure *– non-adherence to stated product needs observed by a user or customer from a product*

fault *– problem that a developer sees*

final release decision *– the act of deciding whether or not* ***releasing*** *a product*

maintainability *– the ease with which a software system or component can be modified to correct* ***failure****s (corrective maintenance), improve performance, or other attributes (perfective maintenance), or adapt to a changed environment (adaptive maintenance) (based on [IEE 1990]) or the probability that, for a given condition of use, a maintenance activity can be carried out within a stated time interval and using stated procedures and resources*
(in formulae: maintainability = 1 / (1 + ***MTTR****))*

MTBF *– Mean Time Between Failures*

MTTF *– Mean Time To Failure*

MTTR *– Mean Time To Repair*

non-functional product needs *- those needs that define product properties and put the constraints upon the functional product needs*

process *– a set of instructions that defines a path to accomplish a predetermined objective (based on [BAY 1999, p. 219]*

product design *– the act of identifying the* ***software architecture***

product needs *- needs regarding the product to be developed seen from the perspective of all* ***stakeholder****s*

product test *– the act of verifying the correct implementation of the defined* ***product needs*** *and* ***product design***

project constraints *- constraints put upon a project and its resulting products*

project control *– the combined act of* ***project definition*** *and* ***project monitoring***

project definition *– the act of making a trade-off between desired* ***product needs*** *and stated* ***project constraints****, resulting in a defined project with defined* ***product needs*** *and defined* ***project constraints***

project monitoring *– the act of monitoring the progress of a project against the result of the* ***project definition***

release criteria *- the particular criteria of a project and its resulting products that are taken into account to make the* ***decision*** *whether or not to release the product*

release decision-making process *- the choice* ***process****, in which one among several release alternatives is selected (based on [COS 1963, p. 334])*

released product *- the product as it is released*

releasing *– the act of formally transferring a product to its intended user(s) and to the authorities responsible for post-release activities like production, service and maintenance*

reliability *– the ability of a product to perform its required functions under stated conditions for a specified period of time (based on [IEE 1990]) or the probability that a product will operate without* ***failure*** *under given conditions for a given time interval*
(in formulae: reliability = ***MTTF*** */ (1 +* ***MTTF****))*

software architecture *- the structure or structures of the product, which comprise software components, the externally visible properties of those components, and the relationships among them [CLE 2002, p. 2]*

stakeholder *- a person whose interests are at stake*

(Note: product = software application, project = software project)