Complexity Aspects of Product Development

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Gutachter: Prof. Dr.-Ing. Prof. h.c. Sándor Vajna
Prof. Dr.-Ing. habil. Stig Ottosson
Prof. Dr.-Ing. Dieter H. Müller

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Lars Holmdahl

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Otto-von-Guericke-Universität Magdeburg

Lars Holmdahl
Standargatan 11A
S-414 61 Göteborg
SWEDEN
www.larsholmdahl.com
and
Otto-von-Guericke-Universität Magdeburg
Lehrstuhl für Maschinenbauinformatik
Prof. Dr.-Ing. Prof. h.c. Sándor Vajna
Postfach 4120
D-39016 Magdeburg
Germany
http://imk.uni-magdeburg.de/lmi/lmi.html

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To Anna, Olof, Peter

The majority is almost always wrong.

Arvid Carlsson
Nobel Laureate year 2000

Abstract

New product development (NPD) projects are becoming increasingly complex, performed in a context that is multi-dimensional, non-linear and hard to model. It is often not sufficient to have a *need* as input for the NPD, but also a *want* or a *wish*. Generally, *need* based NPD projects have stable conditions, while *want/wish* based NPD projects experience unstable conditions, leading to a categorization of NPD methods and organizational approaches as *classic/static* or *dynamic*, depending on their ability to handle *stable* or *unstable conditions*.

Classic NPD methods, from the German school of NPD expressed e.g. in the VDI guidelines 2221 and 2222, and organizational NPD approaches, such as Stage-Gate®, Concurrent Engineering (CE) and Simultaneous Engineering (SE), basically have the view that systems are linear and possible to model. Consequently, with this view, the future outcome of an activity mainly reflects the quality of the detailed long-range planning and how well plans have been followed. Since the result of a successful classical NPD project ideally is a product that is in accordance with what was decided at project start, control of the outcome of NPD activities/processes can, it is belived, be limited to discrete points in time; the gates.

However, the actual situation in NPD is quite the contrary. Therefore to cope with the increasing complexity of NPD, methods such as Dynamic Product Development (DPD) are developed. DPD has an iterative approach that relies on a learning strategy where knowledge is gained through exploration of multiple possibilities. Therefore, short-range plans can be detailed, while long-range planning is markedly rough. DPD prescribes a number of rules of thumb that when used, were found to emerge into a control structure that helped team members keep a high development tempo, making it possible to deliver products that are well suited to market at delivery time.

In order to investigate the relevance of DPD to wish/want projects, Participation Action Research (PAR) was applied to the two case projects. PAR is a qualitative research method by which the researcher takes active part in the studied project, thereby gaining access to areas that are closed to other researchers, yielding observations that may otherwise go unnoticed. Case 1 was an effort to expand a client's business into a new market. Case 2 was a disruptive business innovation project. The analysis is performed against a backdrop of complexity theory.

It was found that early sales should be stressed in order to gain valuable feedback e.g. of the circumstances that the product is intended for, forcing potential customers to "show their hands", etc, thus gaining new knowledge and a chance to iterate. Misconceptions can therefore be corrected early when it is still easy and not to expensive to do, yielding a higher development speed than if corrections had been taken late in the project when changes are always costly.

Collocation of the team around the project leader (PL) was beneficial for sensing the state of affairs on a micro level as well as to offer team guiding opportunities. Information could spread fast, which in turn cut down on information waiting time, thus speeding up the tempo. Principally this was a learning strategy of dynamic adaptation, relying on making use of the latest gained knowledge.

Further it was found that, in a wish/want project, there is no simple transformation of a specification into product design but an intense interaction between prodject goal and product characteristics as they evolve, whereby product specifications emerge from project activities. Project action plans are useful and should be stressed over timelines, which are just a snapshot of what is believed at the time. Flexibility and speed is gained if timelines are substituted by reporting of results and an intense dialogue between those involved.

This thesis shows the benefits of the tight, vigorous control structure of DPD.

Abstrakt

Prozesse zur Durchführung von Neukonstruktionen werden zunehmend komplizierter, da sie in einem Umfeld komplexer Systemen durchgeführt werden müssen, die mehrdimensional, nichtlinear und schwierig zu modellieren sind. Hinzu kommt, dass es – auch aus geschäftlichen Gründen – heute nicht mehr ausreicht, eine Neukonstruktion lediglich durch eine aktuelle konkrete *Nachfrage* auszulösen, sondern es muss auch auf (möglicherweise noch latente) *Bedürfnisse* oder *Wünsche* reagiert werden. Prozesse für Neukonstruktionen, die von einer *Nachfrage* ausgelöst wurden, laufen unter stabilen Bedingungen ab. Dagegen laufen Prozesse, die von *Bedürfnissen* oder *Wünschen* ausgelöst wurden, unter instabilen Bedingungen ab. Dies führt zu einer Einteilung in *klassische* und *dynamische* Ansätze, je nachdem wie diese Prozesse mit ihren Methoden und Organisationsformen mit *stabilen* und *instabilen Bedingungen* umgehen können.

Klassische Ansätze (z.B. die Konstruktionsmethoden der deutschen Schule, wie sie in den VDI-Richtlinien 2221 und 2222 zusammengefaßt sind) und organisatorische Ansätze (wie z.B. Stage-Gate®, Concurrent und Simultaneous Engineering) gehen grundsätzlich davon aus, dass Systeme linear und modellierbar sind. Daraus folgt unter anderem, dass das zukünftige Ergebnis einer Aktivität wesentlich von der Güte der Langfristplanung und von dem Befolgen dieses Plans beeinflusst wird. Da der klassische Ansatz idealerweise zu einem Produkt führt, das genau die Eigenschaften enthält, was zu Beginn des Projektes entschieden wurde, kann die Erfolgskontrolle auf einzelne Zeitpunkte (Tore und Meilensteine) begrenzt werden.

Allerdings ist die heutige Situation eine gegenteilige, weil sie zunehmend komplizierter und dynamischer wird. Zur Beschreibung und Beherrschung steigender Komplexität und instabilen Bedingungen werden dynamische Methoden, wie z.B. die Dynamische Produktentwicklung (DPD) entwickelt. DPD ist eine auf den Anwender orientierte Philosophie. Typisch für DPD ist eine iterative und präzise Kurzfristplanunge und eine grobe Langfristplanung. Da sich komplexe Systeme wie die Produktentwicklung laufend verändern, werden in der DPD Faustregeln vorgeschlagen, mit denen die Teammitglieder in der Lage sind, ein hohes Entwicklungstempo durchzuhalten. Damit können sie Produkte entwickeln, die zur Lieferzeit "gerade richtig" sind. Bei DPD muss der Projektleiter geistig und physisch im Mittelpunkt des Geschehens sein, um unverzüglich Rückkopplung von den Entwicklungsaktivitäten zu bekommen und um, falls erforderlich, Gegenmaßnahmen einzuleiten. Um diese Vorgehensweise zu unterstützen, wird eine neue organisatorische Form, die sogenannte "planetarische Organisationsform" vorgeschlagen.

Um die Relevanz des DPD-Ansatzes für durch Bedürfnisse und Wünsche angestoßene Neukonstruktionen zu untersuchen, wurde das IAR-Verfahren (Insider Action Research) auf zwei beispielhafte Neukonstruktionen angewendet. Im ersten Fall ging es um die Ausweitung der Geschäftsfelder eines Unternehmens durch eine neue Produktreihe, beim zweiten Fall um ein neues Softwareprodukt, mit dem eine bedarfsgetriebene Simulationsrechnungen über das Internet erfolgen kann. Die beiden Studien zeigten, dass die enge Kontrollstruktur von DPD in Verbindung mit der Anwendung von Faustregeln es möglich machte, beide Projekte erfolgreich zu beenden.

Obwohl in DPD bereits früh mit dem Vertrieb zusammengearbeitet werden muss (was klassische Methoden nicht vorsehen), wurde in der Arbeit festgestellt, dass diese Zusammenarbeit deutlich verstärkt werden sollte, um einen besseren Eindruck von der Umgebung zu bekommen, in der das Produkt eingesetzt werden soll. Eine regelmäßige Präsenz des Projektleiters führte zu einem intensiven Dialog mit den Teammitgliedern und zu einer laufenden Berichterstattung über den aktuellen Projektfortschritt. Damit konnte auf Störungen zeitnah reagiert, Missverständnisse und Entwicklungen in eine falsche Richtung konnten rechtzeitig und kostengünstig korrigiert werden. Ergebnis war eine höhere Entwicklungsgeschwindigkeit als bei den Fällen, bei denen Korrekturen erst spät im Entwicklungsprozess erfolgen und dann hohe Änderungskosten nach sich ziehen. Da sich in der planetarischen Organisation Informationen schneller im Projekt ausbreiten, konnte die Wartezeit auf Informationen verkürzt und das Projekts fühlbar beschleunigt werden. Unter sofortiger Nutzung des laufend erworbenen Wissens kam es auch zu einem kontinuierlichen Erlernen der Fähigkeiten zum dynamischen Anpassen der Projektarbeit an neue Gegebenheiten.

Acknowledgments

This thesis is the result of a long journey that started in 1997 when I first met Professor Stig Ottosson. A few months after finding employment with Prosolvia AB, Professor Ottosson as director of research and I as project manager, we both attended a meeting regarding projects and product development. At that meeting, we started a discussion that has lasted since.

Over the years of discussion, or tuition really, Professor Ottosson has urged me to write this thesis. Thank you Stig for pushing me to take this step!

I would also like to thank Professor Sándor Vajna, at Otto-von-Guericke-Universität Magdeburg, both for accepting me as PhD student at his chair, and for most valuable advice and feedback on the late drafts of this thesis.

For valuable guidance and enlightening scientific discussions regarding this work, I thank my supervisor Dr.-Ing. Evastina Björk, presently assistant professor at the College of Halmstad.

However, foremost I thank my wife and family for their consideration and understanding.

Gothenburg, September 2006

Lars Holmdahl

Abbreviations

AR	Action Research
B2B	Business-To-Business
BAD	Brain Aided Design
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacture
CAS	Complex Adaptive Systems
CAx	Computer Aided X
CE	Concurrent Engineering
CEO	Chief Executive Officer
CFD	Computational Fluid Dynamics
CMAJ	Canadian Medical Association Journal
CNPD	Concurrent New Product Development
COD	Calculation On Demand
CT	Communication Technology
CTH	Chalmers University Of Technology
DfX	Design for X
DPD	Dynamic Product Development
EDM	Elektronischen Datenmanagement
EKP	Emergent Knowledge Process
FAQ	Frequently Asked Questions
FEA	Finite Element Analysis
FEM	Finite Element Method
FMEA	Failure Mode and Effect Analysis
FRT	Frontec Research & Technology AB
GUI	Graphical User Interface
HTML	Hyper Text Markup Language
IAR	Insider Action Research
IPD	Integrated Product Development
IPE	Integrierte Produktentwicklung
LCC	Life Cycle Cost
LHMD	Light Head-Mounted Display
MAD	Model Aided Design
MDS	Material Data Sheet
MSEK	Million SEK
NPD	New Product Development
NSD	New Service Development
PAD	Pencil Aided Design
PAR	Participation Action Research
PD	Product Development
PDM	Product Data Management
PDMA	Product Development and Management Association
PL	Project Leader
PM	Project Manager
PRT	Prosolvia Research & Technology AB
QFD	Quality Function Deployment
RFQ	Request For Quotation
SE	Simultaneous Engineering
SEK	Swedish Krona (monetary unit)
SG	Stage-Gate®
SMEs	Small & Medium Enterprises
USAF	United States Air Force
VCC	Volvo Car Corporation
VDI	Verein Deutscher Ingenieure
VOV	Volvo Olofströmsverken
VR	Virtual Reality

Contents

1. Introduction

The welfare of private enterprises and thus of geographical regions and even nations as a whole depend on the production and sales of products. At the marketplace companies continuously compete at an ever-increasing pace by launching improved and new premium products that are the result of new product development (NPD[1]). It follows that the study of product development (PD) with an inclination of improvement is of the greatest concern for a nation, geographical area and the single company.

Opposed to the Newtonian, linear, ordered, conception of the world, there is, since the last couple of decades, a growing understanding of the world as a complex system, and a growing interest in complexity theory and its application to social systems. Since PD projects and especially NPD projects are complex social systems, one would expect to find a vast literature on the subject of complexity aspects of PD. However, this is not the case. The complexity aspects of PD and NPD has not been studied, or at least not been reported in literature, except in just a few cases (e.g. Ottosson 2003, Brown and Eisenhardt 1997) and then not in any depth.

By, to some extent, applying complexity theory, this thesis aims to enhance the knowledge of NPD projects and the understanding of theory, and to give recommendations of how to improve NPD theory so that a more satisfying outcome of NPD undertakings can be achieved.

1.1. Product development

Product development is a collection of activities and processes that utilize the judgment and skills of individuals that organize, communicate, solve problems, create ideas and learn, in order to turn information and resources into a situation from which the company can produce and sell profitable products. Product development then is *the creation of requisite conditions for the production and sale of at least one new product*.

For many companies product development is a viable strategy. However, to choose a product development strategy/method regardless of its substance will not guarantee success. There is a competition between cultures, in which the company that has the most proactive and entrepreneurial culture has a long-term advantage over its competitors (Andersén 2005).

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[1] NPD is a well-established abbreviation in scientific literature written in English, the language of science, and of this thesis. Therefore, the author will use NPD although in German it stands for an unpleasant political party.

It is reasonable that a product development strategy for to be efficient and effective is in harmony with modern knowledge on how to organize, how skilled people solve problems in real life, and how to create an environment that supports and enhances these activities.

The environment of product development in a wider sense is society as a whole. More specifically, however, it consists of users, customers, competitors, laws and regulations, which are all co creating, as well as being influenced by, fashions and trends, that are subject to erratic change. Because humans with their ideas, emotions, hope, and desire that shift and evolve in an unforeseen and often unexpected way, are in themselves complex.

We see that the environment and conditions for product development, as well as product development itself, are *complex* (e.g. Ottosson 2003, Jönsson 2004). A successful strategy therefore should be designed to handle this complexity.

1.2. Research idea

In product development literature, we find diagrams and flow charts that prescribe the organization of activities and what methods to use. However, the "irrational" tendencies of the human mind are often forgotten (Jönsson 2004). Furthermore, it is not even self-evident what constitutes an organization, such as a project team (Santos and Eisenhardt 2005). Morgan (1998) gives more than eight different metaphors for an organization (a machine, an organism, a brain, a culture, a political system, a psychic prison, an attractor[2], a dialectic system, an instrument of domination, and combinations of these). In addition, the shifting conditions and complexity of the environment, as well as the complexity of the project itself, are often neglected.

In order to study complexity aspects of NPD, two NPD projects in a Swedish consultancy company have been studied. The first case is about helping a customer company expand into automotive industry rack business, through the development of a new rack[3] and other activities. The second case is an internal development project. A new business-to-business (B2B) process was developed with the intention of creating a disruptive business innovation (Brandt 2000, Bergh 1999, Lundgren 1999A and 1999B). This is also known as new service development (NSD). The author was the project leader of both projects and the second project's initiator.

The two cases were untypical in the sense that the lions share of the turnover in a Swedish consultancy company comes not from running development projects, but

[2] In the complexity theory sense of the word.

[3] A rack is a pallet made of steel for carrying parts such as stamped sheet steel (fenders, body sides, etc), windows, engines, etc, from the manufacturers production unit to the assembly line of the carmaker. There are e.g. more than 60 000 racks owned by Volvo Car Corporation used for transporting goods from suppliers to the Volvo assembly plants.

from hiring out engineers to customers, or performing "low level" routine jobs, such as building CAD models or creating meshes for FEA. However, the studied cases are, in the experience of the author, representative of this kind of complex development projects.

Further, in the experience of the author, people often agree to the principles of a specific PD method, but when it comes down to action, they follow some other method, some ad hoc method, or no method at all. Others have also noted this effect (e.g. Bragd 2002, Jönsson 2004). Therefore, the great challenge to a project leader of a product development team is to *make people harmoniously cooperate efficiently towards a common goal during uncertainty and with a deficit of information.*

The theory governing this author's actions as project leader in the two studied cases, came from Dynamic Product Development (DPD), as presented in (Ottosson 1999A, 1999B and 1999C), maneuver thinking and some ideas from complexity theory[4].

The companies and engineers involved were not subscribing to any special product development method, leading to a rather heterogeneous environment in Case 1. However, at project start in Case 2, the project leader explained the principles and methods of DPD, which were subsequently put to use by the team.

To investigate the two cases it was felt that the proper research method to use, would be Insider Action Research (IAR), and especially Participation Action Research (PAR) from the position of project leader, figure 1.1.

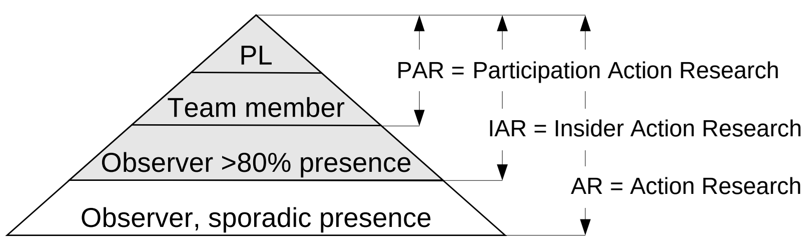

Figure 1.1. Research mode depends on time spent in the system (modified from Björk 2003). PL = Project Leader.

The two projects were completed successfully, seen from a technical point of view. Commercial expectations were not met however. The projects were recorded in memory, documents and artifacts. The author's experience was processed through a dialog with the scientific community and through frequent consultations to the scientific literature, especially during the last years of the work.

[4] See section 3.3 Complexity

1.3. Research questions

Based on the study of the two cases, the aim of this thesis is to answer the following research questions:

1. What complexity aspects of product development, can be found?
2. What requirements for successful execution of PD projects, can be found?
3. Which improvements to the dynamic product development (DPD) method can be proposed?

1.4. Disposition of the thesis

The disposition of this thesis, chapter by chapter, is as follows:

1. **Introduction,** introduces the subject of this dissertation.
2. **Product development, state of the art,** presents the main product development methods and theories.
3. **The complexity of product development,** gives a description of areas not covered by product development theories specifically, but is of importance for the understanding and research of the complex nature of product development.
4. **Research on product development** discusses research methodology. The qualitative method of participation action research is presented. Different standpoints are given, as represented by articles from scientific journals for the last 15 years regarding objectivity.
5. **Case 1 – Becoming a rack producer** describes the first of the two studied cases in a narrative way, almost day by day.
6. **Case 2 – COD, Calculation On Demand** describes the second of the two studied cases in a narrative way. The project is described mainly week by week, but occasionally day by day.
7. **Analysis and discussion of Cases 1 & 2,** experiences from the two cases are analyzed and reflected upon.
8. **Conclusions,** contains the conclusions drawn from the two cases and the analysis and discussion in chapter 7, and gives and discusses answers to the research questions.
9. **References,** contains the references referred to in the text.

Appendices contain information and documents that clarify and enhance the understanding of the text but are deemed not necessary for the comprehension of the case descriptions.

This thesis contains an intricate structure of arguments that is not very easily illustrated by words alone. In order to clarify, part of this structure is schematically shown in figure 1.2. Further, in figure 1.3 it is shown, again schematically, how different chapters cover this structure.

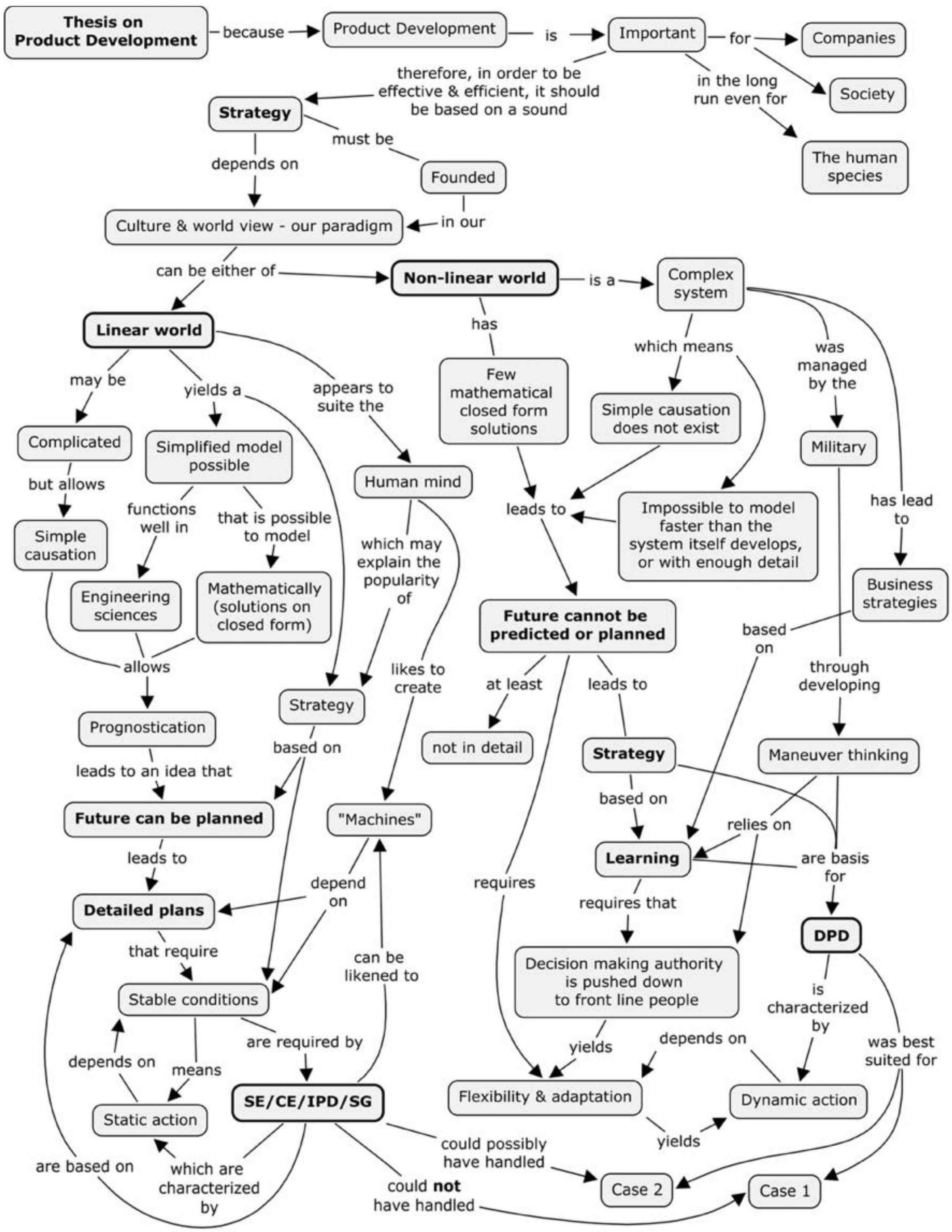

Figure 1.2. Schematic picture of part of the argument structure of this thesis

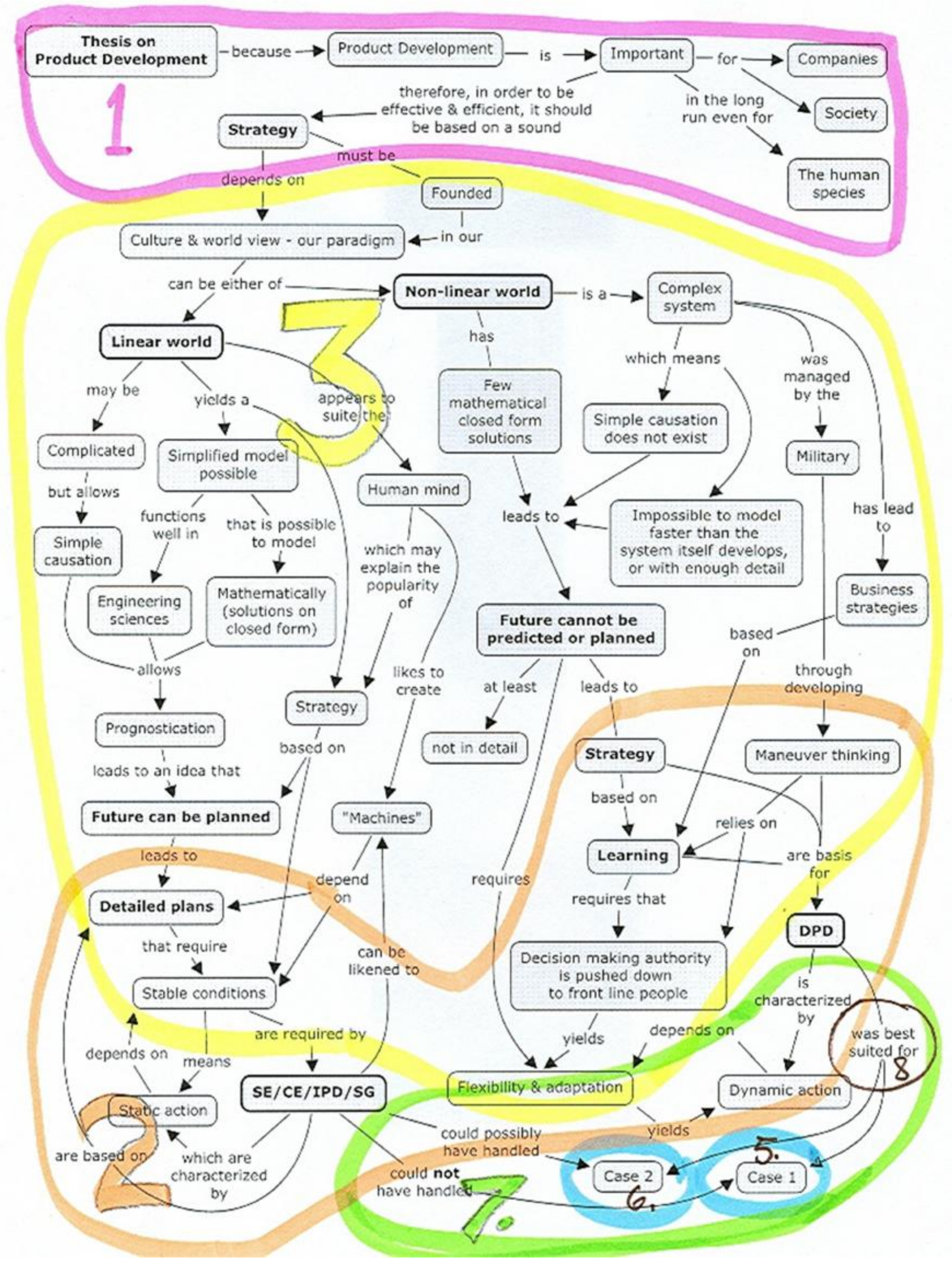

Figure 1.3. Schematic illustration of arguments distribution connected to the different chapters

1.5. Caveat

The language of science is English. It is also the language of this thesis. Although there most certainly are many valuable texts written in German, Spanish, Japanese, etc these texts are left out as the author does not know these languages. References therefore are almost completely made to texts written in English.

2. Product development, state of the art

2.1. Product development is a learning process

Anyone who has ever developed new products from the very first ideas all the way into production has experienced how one "gets to know" the product's characteristics during product development. Thus, PD can be said to be a learning process (Highsmith 2004), or a knowledge managing process (Adamides and Karacapilidis 2004). Knowledge is accumulated until requisite conditions exist for the production and sale of at least one new product.

That PD is a learning process may explain why people that have no experience of PD, want to be reassured and have guaranties, as if it was possible to develop a new product in a straight line from start to finish, as if you were already familiar with the territory that nobody has ever visited.

Learning is important to every part of the company, but the objective of a non-product development process such as production is not learning, but to repeatedly produce as error free work result as possible. When the best production method for a specific product has been found, learning stops and is exchanged for a meticulous repetition. However, for product developers two days are never alike as they explore, make use of their findings, and adjust to them, partaking of an intense learning process.

2.2. Development drivers: wish, want, and need

There are several ways to systematize product development methods. One way is to characterize based on whether the method handles only stable conditions or if the method also can handle unstable conditions, yielding respectively *static* and *dynamic* methods. Another way is to recognize what drives, or initiates a product development effort. This can be a customer *need*, a *wish*, or a *want* (Ottosson 2006).

We do not feel a need for something that does not exist. Two hundred years ago, people did not feel, or express, a need for mobile telephones, aircrafts, or personal computers, since these products did not exist at the time. A need driver is based on existing products, and may result in the development of a new variant, or new to the company copy, of an existing product. A need does not take us out of the ecology of present products.

Two hundred years ago, a few individuals had wishes for aircrafts (e.g. Stringfellow and Cayley[5]) and computers (e.g. Babbage[6] in England). However as the first aircrafts or computers were built there were individuals that also wanted to have an aircraft, or a computer.

We have (Ottosson 2006):

A wish: there is no such product, only the wish for such a product by, often, a single or just a few individuals.

A want: there exists one or just a few, examples of a product. Alternatively, a product may be produced and in use, but lack some characteristic that would make it better suite a new situation or user/customer. Then a want for the new product variant may exist.

A need: the product is relatively common.

There can be a greater sense of urgency in the case of *need* and *want* products than is the case with *wish* products. Often the technology used is more uncertain and untested in the case of *wish* products (Ottosson 2006).

2.3. Business possibility/opportunity

In a commercial company, PD is normally part of a business opportunity of some kind; whether it is a question of market pull or technology push, figure 2.1.

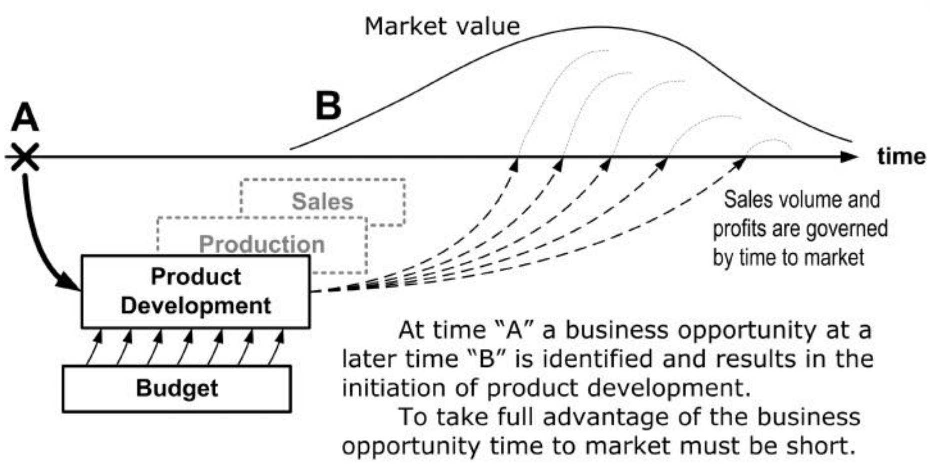

Figure 2.1. The principal requisites for product development

At time A there is identified, or prognosticated, a business opportunity at time B. The market value varies over time (the solid curve) for the product that was identified at A to have a market potential at B. There are three possibilities.

[5] http://en.wikipedia.org/wiki/First_flying_machine

[6] http://en.wikipedia.org/wiki/Charles_Babbage

A < B, as in the figure. This case requires looking into the future, to predict/guess what the market will look like. We have an uncertainty that must be handled by flexibility and adjustment (reorientation) to shifting circumstances. There is uncertainty about market potential, if the product can be technically realized at the right cost, an uncertainty about end price to customer, etc. All this taken together makes any detailed planning of the project rather futile. This can be a *wish* situation.

A = B. Now we are in a hurry if we want to capitalize on the opportunity. This can be a *want* situation.

A > B. Market has been there for some time and one or several actors are active on the market. This is typical of a *need* situation.

Often, and especially for consumer products, the product's success depends heavily on company time-to-market ability (Kumar and Midha 2004), and in some cases, time-to-volume (Minderhoud and Fraser 2005). As hinted by the dashed lines in figure 2.1, sales volume, market share and profit are strongly reduced by delayed market introduction (Rosas-Vega and Vokurka 2000, Smith and Reinertsen 1995, Wheelwright and Clark 1992).

2.3.1 The need for speed

The world around us appears to change faster than before. Product life is quickly getting shorter (Cooper 1998, Minderhoud and Fraser 2005), which influence cash flow, figure 2.2.

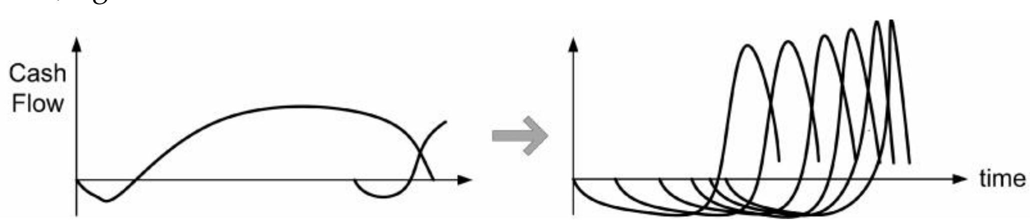

Figure 2.2. Cash flow curves of a few decades ago and for today (effect emphasized).

Market dynamics increase, fashion changes faster, trends come and go, and product life span decreases. New technology is constantly developed that can make the old one – just old. New legislation change conditions for design, production, sales, service and destruction/recycling of products. Time-to-market and for consumer products: time-to-volume is critical; a little too late and the product flops (Minderhoud and Fraser 2005). Fast developers of new products consistently gain competitive advantage over slower developers (Willis and Jurkus 2001).

Therefore, it is desirable to **shorten development time**, which can only be done through a reorientation and a decision to **use methods that are more appropriate** (the compression of traditional methods has not been successful (Vandenbosch and Clift 2002, Minderhoud and Fraser 2005)).

If product development is started with a detailed specification and a detailed timeline and if product development is seen as a question of delivering according to specification and to follow the plan, then that can be called *static product development* (Ottosson 1999B). If on the other hand product development is continuous and flexible with agile adjustment to shifting circumstance, making use of new knowledge as it presents itself, and setting up the organization to react quickly to new impulses, then we have *dynamic product development*, table 2.1.

Static view	Rigid forms
(Govern with structure)	Central governing
	Linear thinking
	Detailed plan (equates to an ability to see into the future)
	Scientific Management, machine metaphor
	Follow the plan
Dynamic view	Flexible, formless
(Govern with visions & knowledge)	Decentralized, empowerment, personal responsibility
	Nonlinear, complexity based thinking, complex adaptive systems (CAS)
	Self-organizing
	Not plan able, except coarsely or for near future only
	Flexible adjustment to change
	Govern with a vision

Table 2.1. A comparison between the static and the dynamic view on product development (Ottosson 1999B).

Methods that can be said to be dynamic are *agile programming* (Highsmith 2004), *extreme programming* (Tångring 2000), *dynamic product development* (Ottosson 1999B), and *Flash development* (Vandenbosch and Clift 2002).

2.4. Need based product development

Need based product development is often characterized by detailed plans and rigid methods. A typical saying is: “plan the work and work the plan” (Halsey 1999, Dant and Kensinger 1997). The need based, static, methods stem from a control culture (Pryor and Shays 1993), based on determinism, Scientific Management, and machine metaphor (Ottosson 1999B).

It appears that most people want to have a tidy, well-organized workplace and checklists to follow. This could be one reason behind the resistance to dynamic thinking and the preference for static, need based, methods. Not until practitioners have gained considerable knowledge and accumulated a lot of experience can they utilize dynamic methods fully (Ottosson 1999B). Until then static methods must suffice, one might add.

2.4.1 Serial/sequential product development

Serial product development, in which different units are responsible for each stage in the process (Stallworth and Kleiner 1996), is one of the oldest of the product development methods. It is also called the relay race method because the baton is first carried by one department, then by another department, and so on (Rama and Herbig 1996), figure 2.3.

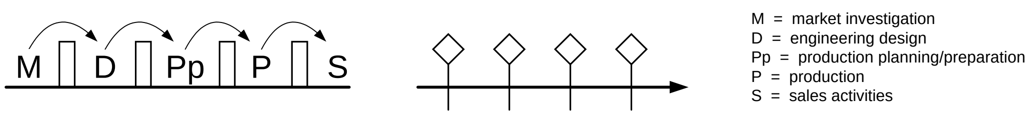

Figure 2.3. The left figure is the relay race method, after Ullman (1997)

The walls between departments in figure 2.3 have a striking resemblance to gates in a stage-and-gate method (the right part of figure 2.3). In organizations where serial product development is used, people involved in development, even within a single department, are often placed separate from each other.

There are serial/sequential product development drawbacks:

- The design engineers may have very little contact with users of the product to be developed, since they are designing to a specification provided by the market or sales department (Ottosson 1999B).
- It is a slow method. There is a long time from start of development to market introduction (Moller and Lee 1999). In addition, this "over-the-wall-mentality" of serial PD can cause project overrun and degrade performance (Jussel and Atherton 2000).
- There is poor internal communication (Bhuiyan et al 2006), especially between upstream and downstream phases (Rahim and Baksh 2003). This can lead to sub optimization and entrenchment between departments and other costly errors (Hoopes and Postrel 1999, Rama and Herbig 1996). People may come to hold rigid opinions that can be difficult to back down from without losing face (Ottosson 1999B).

- In a turbulent business environment, serial product development processes are inefficient and likely to lead to early obsolescence (Iansanti and MacCormack 1997).

In serial PD, management governs with rules, detailed planning, long detailed specifications, and reorganizations (Mikaelsson 2002).

One reason for using serial development is probably that management does not want to let go of detailed plans and micromanagement (even from afar), since they give a feeling, or illusion, of control (Ottosson et al 2000). Another reason is that buildings and the organization itself have been made for serial development (Ottosson 1999B). Through their physical layout, they support and enforce serial development.

It is common to find serial product development even today (Björk 2003). The author has experienced serial development in among others; a world famous camera manufacturer (design did not speak to production, just "tossed" in the drawings "through a hole in the wall"), and a medical supply company where the designers of surgical suction and wound drain devices had never observed a surgeon use their designs!

2.4.2 Semi parallel product development

If activities in serial development are pushed together so that concept development starts before market research is finished, etc, then we have semi parallel development, figure 2.4. This is one way to increase speed compared to serial product development (Vandenbosch and Clift 2002, Terwiesch and Loch 1999).

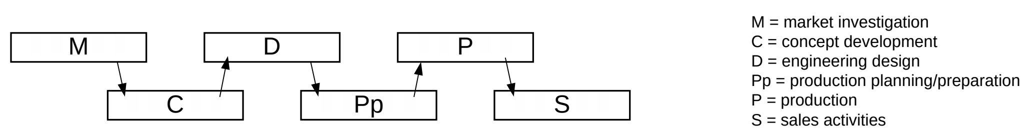

Figure 2.4. In semi parallel development, activities are overlapping

At a visit to Whirlpool Sweden AB in August 1999, it was described to the author how they when developing new microwave oven models had reached a substantial saving in time by pushing together concept development and detail design, figure 2.5. It was found that the interaction between concept development and detail design (indicated by arrows in figure 2.5) resulted in an important increase in efficiency (Lindblom 1999).

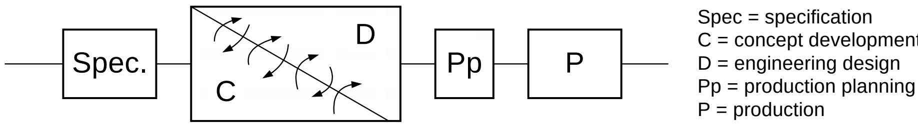

Figure 2.5. By pushing together concept development and detail design, there was a substantial saving in time at Whirlpool Sweden AB (Lindblom 1999)

The increased efficiency resulted from the large number of quick iteration loops and "what if" checks made possible by the parallelization of concept development and detail design. In this way, it was possible to go further into the unfamiliar as regards concept development than before.

The triangular shapes in figure 2.5, indicates that from the start of the activity, concept development dominated over detail design. While at the end of the activity, the reversed was true.

There are several installments of semi parallel methods similar to that of Whirlpool Sweden AB that the author has come across as a consultant project manager. There is e.g. the Vee-model (Forsberg et al 2000) used by Visteon. This model is essentially similar to methods used by many automotive manufacturers such as Volvo Car Corporation and others.

2.4.3 Parallel product development

Parallel product development methods are called parallel because there is a more or less simultaneous start and execution of activities in all involved functional departments of the company. The work within each department, however, is not necessarily performed in parallel, which would have required e.g. concept development performed in parallel with detail design, but may still be performed in a serial fashion, separated by gates.

2.4.3.1 Simultaneous engineering, SE

In the late 1970s and early 1980s, the concept of simultaneous engineering (SE) began to break down the walls between departments and later between tier one supplier and customer, emphasizing the simultaneous development of the manufacturing process with the evolution of the product. Simultaneous engineering was accomplished by assigning manufacturing representatives to be members of design teams so that they could interact with the design engineers throughout the design process. The goal was the simultaneous development of the product and the manufacturing process (Ullman 1997).

The effective communication thus achieved between design and process engineers and the use of CAD and CAM in combination with the removal of departmental barriers, either real or imagined, has been reported in some cases to reduce time to market by one-third (Evans 1988) and further, there has been a reduction in manufacturing operations yielding savings in equipment and service (Meade 1989).

2.4.3.2 Concurrent Engineering, CE

The Product Development and Management Association[7] (PDMA) define Concurrent Engineering (CE): **"**When product design and manufacturing process development occur concurrently in an integrated fashion, using a cross-functional team, rather than sequentially by separate functions. CE is intended to cause the development team to consider all elements of the product life cycle from conception through disposal, including quality, cost, and maintenance, from the project's outset. Also called *simultaneous* engineering." CE and SE are sometimes used interchangeably; see e.g. Kumar and Midha (2004) or Sweeney (1992, 1991).

The cross-functional collocated CE-team works in a CAE environment using rapid prototyping and tools such as QFD, FMEA, DfX, etc. CE is considered an ideal environment for the DfX approach to product development (Meerkman and Koch 2005). The goal is shorter time to market and higher profitability by addressing the design and manufacture process from a customer standpoint. The key components of concurrent engineering are actually quite simple (Jarvis 1999):

- A clear understanding of **customer needs** at the start of the project
- **Stability in the product specification**
- A structured, systematic approach[8]
- The ability to build and support effective teams
- A realistic project plan based on application of the defined product development process
- The availability of resources inherent in the project plan
- Early involvement of all team members to support the parallel design of product and process
- Appropriate technological support to minimize time involved in physical prototyping and testing

[7] http://www.pdma.org/library/glossary.html

[8] What is meant by "structured and systematic" is not self-evident, but dependent on perspective. Is it, for instance, a question of forcing a structure and predefined order or sequence of activities upon a subject (outside and from above) or is it allowing the inherent structure and order of the subject itself guide development activities?

Design re-use and standardization to minimize the design content of a project. (By applying this approach, Black & Decker has reduced time and cost of development by one half (Ranney and Deck 1995). Also Japanese tier one automotive suppliers experience large gains from designing a huge variety from a few standardized modules (Sobek et al 1999)).

Sometimes CE is foremost seen as a systematic engineering design methodology where design engineers and production specialists interact (Carlson Skalak et al 1997). Based on ideas of systematic design from the VDI Design Guideline 2221, (VDI-Verlag 1987) and Pahl et al (1996), Carlsson Skalak et al (1997) design a CE methodology for smaller companies. It is noteworthy that Carlson Skalak (1997), as many others, mistake milestones for gates.

Although substantial savings in time and money are reported when transforming from serial PD to CE (Bhuiyan et al 2006, Stalk 1988) and especially so due to the use of cross-functional teams (Ranney and Deck1995), there are many companies that have adopted CE but still rely on a serial test and validation process (Hammett et al 1998).

There are drawbacks to CE according to Yan and Jiang (1999):

1. Lack of consideration for the problems arising from shared resources,
2. Its current organizational method is not well suited for product development by small or medium-sized manufacturers (SMEs). The CE method of organization is to rigidly organize teams. For the sake of design, teams have to be assigned sufficient resources, as well as a variety of tools and testing equipment. Consequently, this organizational method is adapted to developing very complicated products when development tasks are heavy. In that case, finite resources are fully utilized. However, the market does not demand only highly sophisticated products. In particular, SMEs usually develop and manufacture medium- or low-complicated products. Thus, if teams in SMEs are organized in a rigid manner, there will be shortages and resources will be wasted.

Its implementation needs considerable reform of the present enterprise organizational structures.

The reliance in CE on QFD is said to reduce cycle time, but it takes considerable time to make it function according to Cristiano et al (2000), who refer to a Japanese mail survey of over 400 companies. The responding companies reported that QFD required a significant amount of time (6 years) to penetrate throughout the organization and two years to systematize. Likewise, Kengpol (2004) talks about “many years”. In individualistic cultures, it is even more difficult to make QFD function than in collectivistic cultures (Nakata and Sivakumar 1996). Further, there is no market forecasting in QFD and it can inhibit innovative creativity (Cristiano et al 2000).

Although many companies have implemented CE, there have been problems with fully utilizing the alleged potential of CE (Hague 2003). Further, in the companies studied by Haque (2003): "…despite the presence of CNPD [Concurrent New Product Development] for many years, its implementation is still not adequate". Even with well-defined stage-and-gate processes there are problems most often stemming from the strength of the functional organization and levels of hierarchy, lack of collocation and empowerment to project teams, weak project leaders, insufficient training, and resources (Haque 2003). The prime enablers of efficient CNPD, are a supportive process-focused organization, and collocated and multifunctional project teams that are knowledgeable of the process (Haque 2003).

2.4.3.3 Integrated Product Development, IPD

The term IPD was first coined by professor Fredy Olsson, who already in the 1970's put forth the then novel idea that integrated teams with members from the four main functions in a company (market, design, production and leading/administration) should be used for the development of new products, figure 2.6.

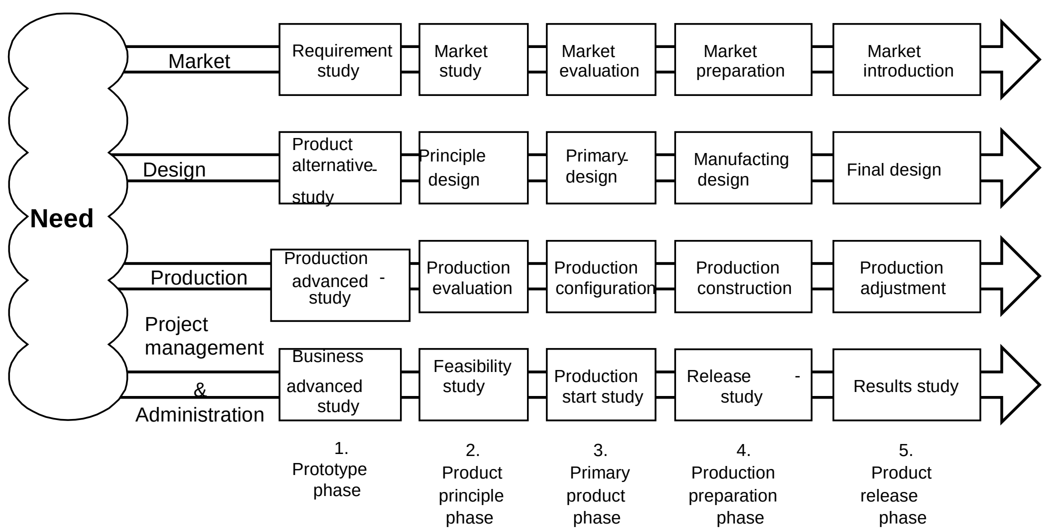

Figure 2.6. The IPD model developed by Olsson (1985)

Olsson's doctoral student Andreasen, removed the leading/administration function from his teacher's model, and did some other changes, in order to stress what he saw as important namely: *market*, *product,* and *production*, figure 2.7.

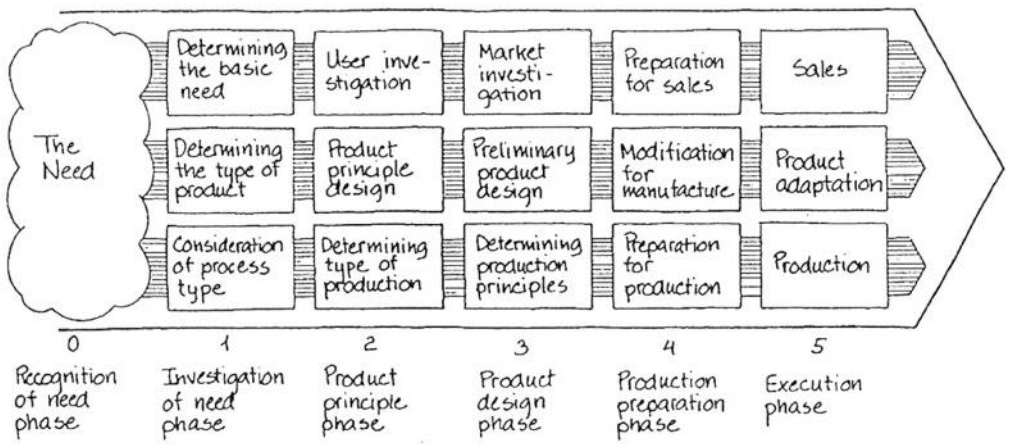

Figure 2.7. The generic IPD model by Andreasen and Hein (1987)

Note that: In Olsson's IPD model there is market introduction, and in Andreasen's IPD model there is sales, starting concurrently with start of production. In neither model are there any sales before start of production.

IPD starts with a *need*, a market pull, sometimes articulated as "Voice of the Customer". The model therefore has difficulties (theoretically) handling technology push products. To be efficient the team should be collocated, something that most industrial office buildings are not intended for (Stallworth and Kleiner 1996). Another difficulty with IPD is the simultaneous start in all functions, which can lead to under-exploitation of resources. The need for presence from all functions can, especially in SMEs, lead to people participating in more than one project at a time.

Today there are many different views of what IPD is. Since market activities are absent or downplayed in SE/CE it can be argued that if market development is added to CE/SE then you have IPD (Andreasen 2002). By integrating the concepts for concurrent engineering and total quality management one gets IPD according to Gunasekaran (1998). Gerwin and Barrowman (2002) in their meta-study of IPD research reported that overlap between departments and functions are the typical characteristic of IPD. Norell (1999) says that:

> "Integrated product development, IPD, is a concept for increasing efficiency in industrial product development through multidimensional integration. IPD is based on a holistic view including products, processes, and individuals.
>
> IPD is characterized by change. New engineering methods, IT-tools and work procedures are continuously being developed and deployed. Basic factors behind IPD include: parallel activities, multifunctional teamwork, structured and front loaded processes, environmental consciousness and individual as well as organizational learning".

PDMA[9] defines IPD as, "A philosophy that systematically employs an integrated team effort from multiple functional disciplines to develop effectively and efficiently new products that satisfy customer needs". [This is a strange definition since it says that customer satisfaction decides whether the method is IPD or not.]

To computer company IBM, IPD is a process described as "…a *stage gate process* for product introductions was deployed across IBM in 1998 called integrated product development (IPD). IPD was and is a systematic process for determining which products and services have the greatest potential…" (Knight 2005). At IBM, all work branches are represented on the IPD team.

CE and IPD are often used interchangeably (Haque 2003, Machine Design 1998, Anderson 1996). The "D" in IPD could, it seems, just as well in many cases stand for "Design", not "Development".

For efficiency, IPD is dependant on *stable design criteria* leading to a lot of attention being paid to product specification work early in the development in order to avoid unfavorable iterations (Norell 1999). IPD is therefore not very flexible and has difficulties adapting to changing conditions. A limiting characteristic of IPD is the division into phases or stages (that can be separated by gates) that the project runs through one after the other. This effectively makes IPD a stage-and-gate method (see next section).

Such stage/phase-gate models can be effective under certain conditions. First, it may work well when the time required to innovate is shorter than the rate of change in the business environment (this is the basic demand for stable conditions). Second, the phase-gate model is, given the first condition, good at controlling quality and reliability (Minderhoud and Fraser 2005).

2.4.3.4 Stage-and-gate processes

Based on quantitative studies that started in the 1970's and by mid 2005 having accumulated a sample of more than 500 North American companies[10], Dr Robert G. Cooper and his colleagues have designed a simple stage-and-gate process known as Stage-Gate™. This process, it is claimed[11], has been adopted by more than 73% of North American companies, making Stage-Gate™ the dominant product development method, at least as seen from an upper management perspective.

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[9] http://www.pdma.org/library/glossary.html

[10] http://www.prod-dev.com/ in September 2005

[11] Ibid.

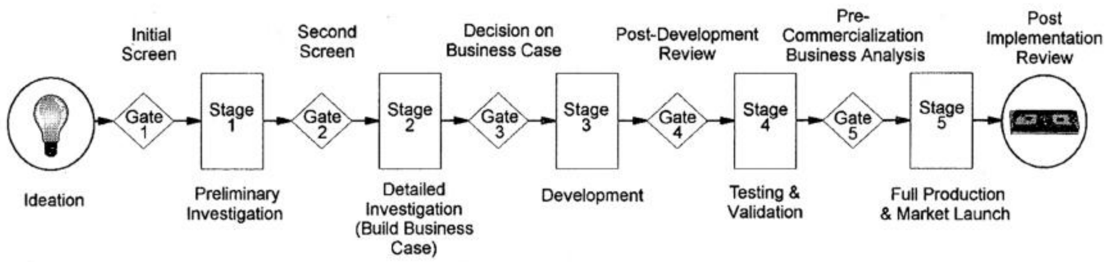

Figure 2.8. The generic 5-stage Stage-Gate™ model by Cooper (1998)

According to Cooper (1998), Stage-Gate™ is a *process management tool* for product innovation [sic]. However, as such it is not without critique, as the following examples show.

- When developing consumer products it is better to start the launch stage up front instead of saving it to last (Rosenau 1997, Schneider 2005).
- If the whistle is blown, in for example Stage 3, then according to Cooper (1998) the project shall be recycled back to Gate 3. Why? The project has already passed Gate 3!
- There comes responsibility with being fully informed. Maybe the attractiveness of a stage-and-gate process is that it allows upper management to effectively distance themselves from the project and responsibility for its performance. It is well known that upper management usually show little interest early in product development projects but increase interest closer to production ramp up and above all they like fire-fighting late in projects that risk failure, because that is a personally low-risk activity (Wheelwright and Clark 1995).

Cooper (1998) enhances the Stage-Gate™ process by introducing "fluidity" which is an alleviation of the dictates of Stage-Gate™ but does not say when to go fluid or where to decide to go fluid. Is it when a need arises, or at a gate? Who decides when to go fluid? The project leader, the sponsor, senior management; Cooper does not say.

Cooper's project leader lacks genuine authority over the project and is therefore, in the opinion of the author, more like an errand boy for the gatekeepers, yielding an obvious conflict between the overall goal, efficiency, time-to-market, etc on the one hand and organizational form on the other. Thus, the project leader may risk his head for taking actions that are the correct ones considering the overall goal of the project. In a non-permissive culture, this will hinder correct action and swift performance.

- This kind of upper management control of projects can have detrimental effects on project performance (Bonner et al 2002).

- How seasoned project leaders notoriously use gates to blackmail functional management for resources and how an OK at a gate is used as proof of "absolution of sins" is shown in Ottosson et al (2000).
- Gates lower development speed, increasing time-to-market (Minderhoud and Fraser 2005, Ottosson 2004A). The Stage-Gate™ process is not designed for speed (Vandenbosch and Clift 2002).

The measure of the value of a stage-and-gate process is how early it can kill a new product candidate before there has been unnecessary spending. The quicker the idea is killed the more money is saved. The Stage-Gate™ process is perfectly rigged for killing new ideas. What's lacking is an idea input process before the Stage-Gate™ process (Buggie 2002). Especially for service products, the Stage-Gate™ light bulb should be replaced by user interaction (Alam 2005). There is too little attention to early stages (Minderhoud and Fraser 2005). There must be a procedure of scanning for ideas/opportunities before the first gate that not only feeds the Stage-Gate™ process, but also utilizes opportunities that not directly lead to NPD (Börjesson et al 2005).

- Timely decisions are vital for any competing organization. However, in a stage-gate process, important decisions are not made when problems and opportunities are discovered; when they are still pending, but instead they are saved for later and brought up at gates.

2.4.3.5 Integrierte Produktentwicklung, IPE

At the *Lehrstuhl für Maschinenbauinformatik*, *Otto-von-Guericke-Universität Magdeburg*, there has been developed a PD model called *Integrierte Produktentwicklung (IPE*) that is a dynamic variant of IPD. Taking off from the work of Ehrlenspiel (1995) and Meerkamm (1994), the human factor including the use of manual methods is stressed, as well as the integration of holistic and multidisciplinary methods (Vajna and Burchardt 1998).

IPE was developed out of the necessity to integrate all fields that take part in product creation, to overcome organization forms that split up work, and to aim beyond the solving of technical problems towards also achieving appropriate operational sequence (Naumann 2005).

IPE focuses on the superior fundamental goals (Naumann 2005):

- Shortening of the time from collection of customer needs up to the manufacturing release of a product,
- Reduction of the product development costs,
- Improvement of product and process quality as well as

- Optimum function and requirement fulfillment.

The IPE philosophy can be used for every product development area in which products such as physical objects, and, to some extent, services, or for example software, are developed (Naumann 2005). The philosophy of IPE contains four aspects, aims, or targets that focus and integrate all necessary factors for the modeling and development of products and services, figure 2.9.

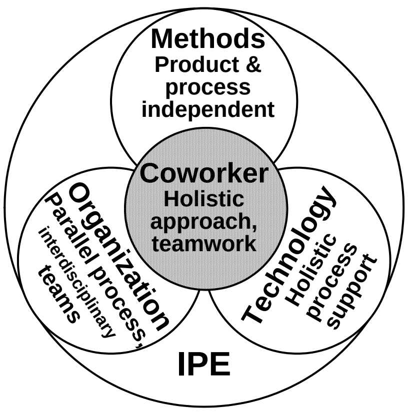

Figure 2.9. The IPE model (Naumann 2005)

- *Organization* integrates dynamic organization forms, e.g. interdisciplinary teams, network structures, or process parallelism.
- *Technology* stands for modern information technologies such as CAx and EDM/PDM as well as new more comprehensive approaches e.g. virtual product development.
- *Method* contains all methods and procedures for the support and follow-up of product development, like e.g. knowledge management, which offers structured aspects on best practice solutions.
- *Coworker*, the human aspect, is located in the center of IPE. Only humans as creative problem solvers are in a position to generate and use knowledge, structure problems and work units, provide organizational structures, find suitable solutions and use the latest technologies.

2.5. Want and wish based product development

Beside Dynamic Product Development (DPD), there are few dynamic product development methods reported in literature. There is *agile programming* (Highsmith 2004), an offspring of the Agile Initiative of the Agile Alliance[12], which is a consortium of software companies. The attitude of agile programming has much in common with maneuver thinking. It is characterized by a string of short incremental, iterative sprints, where tempo, or cadence, has been found to be important for team efficiency (Holler 2006). Agile programming is targeting software development and not general product development even though such aspirations are sometimes ventured in agile programming literature. There is *extreme programming* (Tångring 2000), which is only targeting software development. Further, *Flash development* (Vandenbosch

[12] http://www.agilealliance.org/

and Clift 2002) is described in one article only and does not seem to have any following. Because of these circumstances, the above dynamic methods, with the exception of DPD, are not discussed any further.

2.5.1 Dynamic Product Development, DPD

In contrast to other methods that prescribe a procession of actions, DPD is more of a strategy or doctrine, where the situation at hand prescribes the actions taken. Therefore in DPD there can be no great scheme that declares what to do and in what order. As a consequence of its strategy of opportunistic and continuous adaptation[13] to ever changing circumstance, DPD is like flowing water.

The DPD strategy comes natural in a culture of maneuver thinking[14]. It can be said that DPD is born out of such a culture and even that DPD is the application of maneuver thinking to product development. There is no periodic upper/middle level structure of gates as in stage-and-gate methods, but contrary to other methods, there are low-level rules of thumb or tactics, that in the complex system, that is a product development project, create a midlevel control of the project through emergence[15].

DPD was developed by Dr Stig Ottosson and is described in textbooks and papers (Ottosson 1996, 1998, 1999A, B, C, 2001, 2004A, B, C, D, 2005, 2006). In a recent report, DPD was found to be the best method for SMEs (Elfving 2004). DPD has not yet gained widespread popularity because, maybe, it was so recently introduced, but also, perhaps, because of the lack of strict distancing control instruments as in Stage-Gate™. Controlling a DPD project is equivalent to being fully informed of actions and that means responsibility and nowhere to hide.

In DPD, contrary to other methods, the concept is developed continuously in parallel with product and production process development. For this to work a clear and living vision of the desired result of the work is communicated and encompassed by all involved in the development. In order to achieve agile adjustment to changing conditions (unstable conditions), project planning consists of a coarse long-range plan and a finer plan for the near future, with weekly follow-up reports.

DPD use empowered collocated cross-functional project teams. Team size is continuously adjusted to the need of the work at hand. Such expandable structures where members may move in and out of the team can be very successful (Ancona et al 2002). Teams should have a clear user focus in their work. Products are developed with, rather than for, the user, which has important positive effects (Rowland 2004).

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[13] This is in harmony with Boyd's theories of flexible adjustment to changing circumstances section 3.7.3

[14] See section 3.7.4 Maneuver thinking.

[15] Section 3.3 Complexity.

2.5.1.1 DPD rules of thumb

Contrary to other methods, DPD achieves through a low-level prescription of simple rules of thumb a higher-level effect, so called emergence.

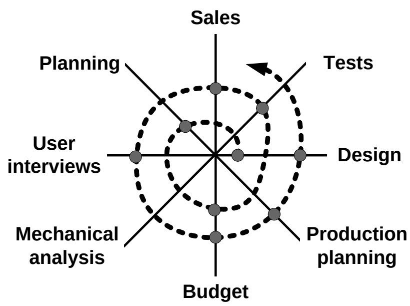

Figure 2.10. Shift between tasks

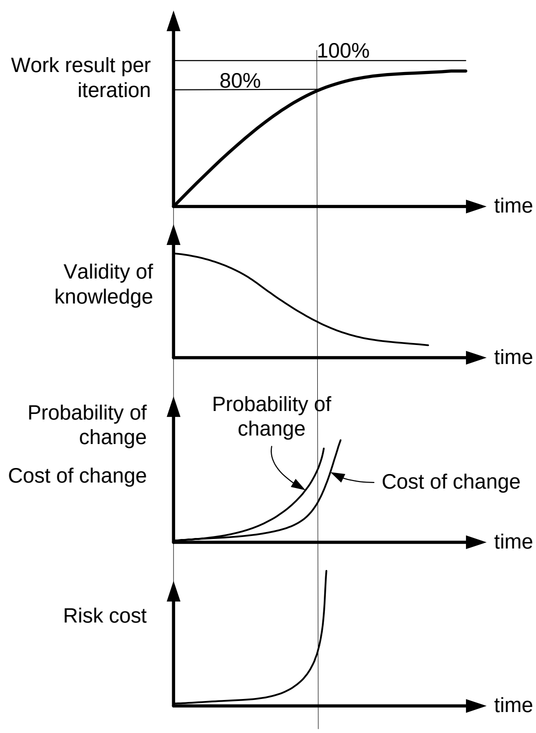

Figure 2.11. The Pareto principle in DPD

1. **Concentrate on the main problem.** Identify the main problem, the big hindrance and attack it. When the main problems have been solved, it is often easy to solve the lesser problems. *If the main problems cannot be solved then effort should not be wasted on the lesser problems, but terminate or redirect the project.*

2. **Like flowing water.** This is a principle in the form of a metaphor. Pass by lesser problems like water flows around smaller obstacles, without solving them just yet, or setting them aside and solving them separately from the main work, perhaps by aid of a special task force. The important characteristic is the flexibility of flowing water and its momentum. If the obstacle is massive, water accumulates and eventually finds a weak point and breaks through. In the same way larger, perhaps critical problems are attacked and resolutely solved with the combined force of team members and project resources.

3. **Switch between tasks.** Creative capability benefits from switching between different problems or work-tasks. Tempo, initiative and money is lost if people spend their time waiting (see e.g. Highsmith 2004, chapter 2). If you for some reason cannot continue with what is at hand, then shift over to what is the next most important thing to do until you are able to go back and continue with the

first work-task, figure 2.10. It has been found that the more experienced and skilled the designers are, the more they iterate between activities (Adams et al 2003).

4. **The 80/20 rule,** the Pareto principle. Initially the work result grows almost linearly with time, figure 2.11. As we get closer to work finished, efficiency diminishes, there is a knee on the curve beyond which there is an asymptotic movement towards 100% finished. Work should make a halt at the knee, at approximately 80% of work finished, for the following reasons.

   The value of knowledge often decays with time. The knowledge we start with is less valid the longer we keep on without replenishing with new knowledge (verify results, coalesce with the rest of the team, etc).

   Therefore the probability, or risk, that we will have to go back and redo earlier work increase progressively the further we go. Furthermore, the cost of design changes increase the longer we continue. Now risk cost is normally defined as probability of change multiplied by cost of change. Therefore, risk cost increases very steeply beyond the knee of the curve.

   It is good practice to stop at roughly 80% finished and then shift to other tasks and in this way verify what one has produced and replenish ones knowledge. A break is also good for ones creativity. During the break, we get new impressions while at the same time the preconscious mind works with the problem.

5. **Continuously develop in parallel the product concept and goals** as you during work gain more and more knowledge of the product and its user. This is adaptation to changing circumstance, which results in better products more in tune with user requirements. The concept is "owned" by the Concept Group, which is also the steering group of the project. The Concept Group members are present in the team for the whole length of the project, thereby forming an important project core that carries the team's history and identity (Ancona et al 2002). The concept group develops the first concept and leads the subsequent development of the concept.

6. **Simultaneously gather facts - analyze - create solutions - test.** The analysis and creation of solutions will yield new questions, which will lead to new inquiries, which will influence analysis and solutions, etc. Therefore, they must all be done simultaneously for maximum efficiency.

7. **Make many small, and few large decisions.** This is the gateless method or the method of "every minute is a gate".

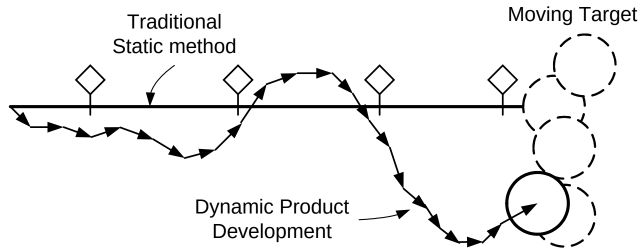

Figure 2.12. Often in PD, one is aiming at a moving target

There is no need to follow a special order when solving problems, except that one should always start at the abstract level and then work downwards to the concrete level.

8. **User vs. customer.** Contrary to other methods that emphasize customers or the mindset that product development serves a number of stakeholders where the customer is one, DPD has a clear user focus. When designing, always have the user in mind! It is far better to design with, than for someone (Rowland 2004). Sometimes the customer and the user is the same person, but often they are not.

   There is more to this: by thinking in user terms, you will pay more attention to user values. To understand the user even better you should become the user. Talk to users, study users, and try to understand how it is to use the product while being very small, very large, light, heavy, etc. This calls for empathic abilities.

9. **Design and verify concurrently.** Not many years ago engineering design of the part/system/total architecture, was followed by the building of prototypes. The prototypes were then tested and test results were analyzed. Often there was no time for redesign in case of failure during test, so the design engineer designed the parts sturdy enough to pass the test. This, of course, was a waste of raw material and money. This is case A in figure 2.13.

   When CAD was introduced, CAD drawings and later CAD models were used for making test specimens. After some time it was realized that the models could be meshed and used for FEA-purposes making the physical testing obsolete16. This is case B in figure 2.13.

[16] This has not completely happened, and will never happen as long as legislation in many countries demands physical tests, such as crash tests of automobiles.

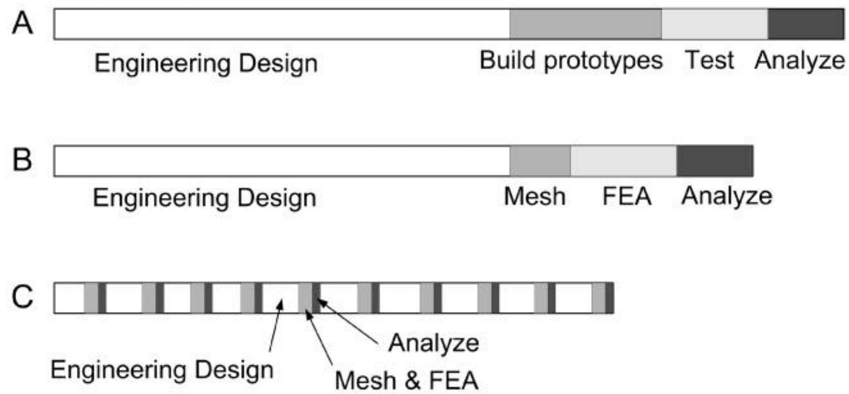

Figure 2.13. Comparison between different development strategies in foremost the automotive industry, A: old-fashioned, B: contemporary, and C: modern (Holmdahl 2003)

Unfortunately, case B has the same drawback as case A - the waste of raw material and money. The reason for this is simple: in both cases, physical tests and FEA are used at the end of the process to verify the design, not allowing any iterative design loops for reason of time shortage. Findings from FEA were not fed into the design process.

The method of DPD, case C, consists of short iterative design-FEA-analyze steps. By using modern software that works in the background of the program and automatically creates the mesh, the engineer can test and modify the design many times during a single day.

By starting out with a coarse FEA-model and making it finer and more precise as the design itself is developed, it is possible in most cases to have the design verified the very instant that it is changed or a feature added. With this method, there is no need for a special validation activity after design is finished, because the design is already optimized as regards strength, noise and vibration, fluid dynamics, etc.

The method of case C allows for quick iterations. This is fortunate because the second time around, the designer will perform faster and better than the first time. For each iteration, the designer gets to know the product and its characteristics better.

It is interesting to see that one author (Ullman 1997, p15-16) acknowledge this by writing: "…after completing a project, most designers want a chance to start all over in order to do the project properly … ". However, Ullman refrains from drawing the correct conclusion, namely that the design method should be of an iterative nature, to allow the design engineers to "do the project all over" many times.

There is an additional meaning to the idea of starting with a coarse concept and then refine it in subsequent steps, sometimes iteratively, and that is - you develop the concept continuously from start of project until finished product. This runs contrary to the established paradigm in engineering design, but is never the less a more efficient strategy for developing products that fit the market situation at product launch. The mindset should be characterized by a preparedness for continues concept development.

10. **Reinvent the wheel.** This is a catchy phrase to remind the developer to be creative first, before looking at what others have done. Because if developers start by inspecting others' solutions, they will be so influenced by what they see that for a long time their own creative ability is seriously hampered.

11. **BAD - PAD – MAD**

    a. **Brain Aided Design – BAD**. Start by thinking! A large part of concept development and engineering design is the joggling of objects in the mind. Design engineers visualize the design and try out different solutions in their mind. It is therefore important to train this ability, and to learn to create the right circumstances, necessary for the ability to function at optimal level.

    b. **Pencil Aided Design – PAD.** Pencil and paper are the most important tools for concept development and for solving problems in engineering design (Salter and Gann 2003). By drawing on paper there is created a direct link between the thoughts in the brain and the visual impression from the picture being drawn.

       Kinesthesia, muscle memory and hand-eye coordination, is at work here. The movement of the hand is important for the brain-activity in finding solutions, especially so for creativity problems. Many pictures are created that are simultaneously viewed and processed by the mind. The paper acts both as memory and as test bed for the seeking of solutions.

       The action is from the abstract towards increasingly detailed solutions. At a suitable level the pen and paper sketching is stopped and the work is continued with a CAD system.

    c. **Model Aided Design – MAD.** It is often useful to build and test some simple models to verify the function of concepts or to increase ones understanding of the concept. Favored materials are model clay, plastic foam, LEGO bits, balsa wood, and cardboard.

       As with PAD, models have merits that computers lack. The tactile feedback and the visual impressions, and the possibility to mimic the real thing differ from when using computers only. With models, the impressions are remembered differently and more vividly.

The forte of using computer software for trying out mechanisms is the possibility to get exact data of displacements, forces, velocities, and accelerations.

In DPD there comes a creative phase of BAD-PAD-MAD before comparing ideas with others' solutions (figure 2.14), while in CE, SE, and IPD concept development starts with benchmarking others' solutions.

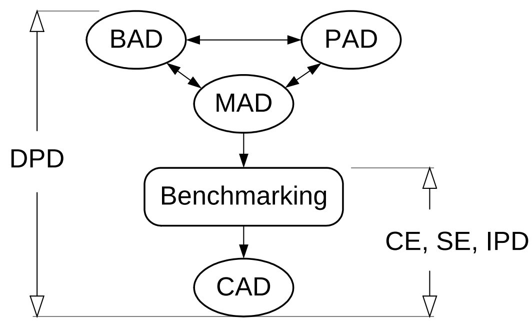

Figure 2.14. Comparison of DPD with CE, SE, and IPD (Ottosson 2004)

12. **Writing on the wall.** The timeline should be plotted out in as large a format as possible and then hung on the wall next to where the team is located. Then it is always visible and serves as a constant reminder (Smith and Reinertsen 1995).

    Changes to the time plan can be written directly on the plot, making them very visible to the team. Further, important information such as descriptions of the user of the product, pictures of its use, and pictures showing the styling and environment where the product will be used is hung on the wall.

    Drawings such as assemblies, sections, and mating surfaces are all plotted and hung on the wall together with conflict areas, unsolved problems, sketches, alternative concepts, etc, so that whenever team members lean back or raise their eyes they fall on the wall and the brain is filled with visual information that feeds the creative process of the subconscious mind.

    This method is extremely powerful, according to the experience of the author, but it seems almost impossible to convince people to use it. Not until they have actually tried, can one convince them.

2.5.1.2 Planning

Due to the complex nature of product development, long range planning is more uncertain than short range planning. Therefore, it is best to create a coarse long-range plan and to make a rolling detailed short-range plan. The closer in time, the more detailed is the plan. This is akin to rolling forecasting in which data used for prediction is updated with the most current observations (Hong and Richardson 2005, p175).

At the end of every week, each team member briefly reports that weeks work results and time, money, and other resources spent, together with a plan for the coming week.

The value of plans is in the planning, which can create preparedness for future actions, a memory of the future so to speak (Cunha and Cunha 2002).

2.5.1.3 Organization

Two aspects of the organization of product development are especially stressed in DPD. They are collocation of the project team, and the use of so-called planetary organizations instead of the common hierarchy.

2.5.1.4 Collocation

The importance of collocation cannot be overstressed. Projects failing to yield expected benefits can be ascribed to this fact. In addition, the physical layout of the building is important (Haynes and Price 2004, Olson 2002, Stallworth and Kleiner 1996). *We shape our buildings, and afterwards our buildings shape us* (Upitis 2004). For practical examples of benefits from collocation, see for example Bunting (2005).

Teamwork depends on constant communication: "In collocated teams, team members frequently report that some of the best discussions occur spontaneously, based on frequent interactions with collocated workers" (Malhotra et al 2001). Through all channels: 1/ hearing the tone of voice, words used, 2/ seeing the body language, clothes used, skin hue, 3/ scent: humans pick up and are affected by pheromones, 4/ tactile information, etc.

Humans have a bandwidth of approximately 10 Mbit/s when meeting face to face. All of this, except less than about 20 bit/s, is subconscious communication (Norrestranders 1999).

Collocation of the team yields the following benefits:

1. The team stays focused. No stealing of team members' attention from other groups,
2. Short communication ways,
3. Easy to have impromptu meetings,
4. Facilitates overhearing, yielding efficient spreading of information:
    a. If for instance the project leader talks over the phone with the client, then the team, by hearing the conversation is informed.

b. This also makes possible spontaneous problem solving which can happen when one team member hears others talk of a problem to which he happens to have a solution.

When collocating the team, the product, or **a model, mock up, etc, of the product to be developed should be placed in the center of the group**. This has many advantages.

1. Works as a reminder of the reason for the team's existence. Helps focus attention to the product.
2. Is a good visualization aid for talks and discussions between team members themselves and between team members and visitors to the team.
3. Shows the status of the project if the most resent version is displayed.

Collocation of team members mean that they all sit in the same room. There should be no obstacles between them visually blocking communication.

In the close vicinity of the open room, there should be small rooms available that can be used by the team, because from time to time there is need for secluded meetings. The project leader might want to talk to a team member, or meet with a sponsor. There is also need for team members to meet for problem solving without being interrupted, and there is need for private conversations and telephone calls.

It is convenient to have large white-boards on the walls and video projectors for projecting for instance CAD models on the white-board. Then the team can draw alternative concept solutions on the white-board on top of the projected image. There are numerous smart aids to project work. One's fantasy is really the limit.

Collocation also means that the project leader must never "hide" in his room isolated from the team. The place of the project leader is in the center of the team.

2.5.1.5 Planetary organization

In DPD a special form of organizing is used (Ottosson 1999D), called planetary organization, figure 2.15. Around a central sun there are planets. These planets can be suns with their own planetary systems. Each planet reports inwards to their respective sun, just as in any hierarchical organization. However, here each planet also sends information circumferentially to every other planet with the same sun. It is the obligation of each planet to keep "sister planets" informed of their actions. This facilitates a fast and high information flow.

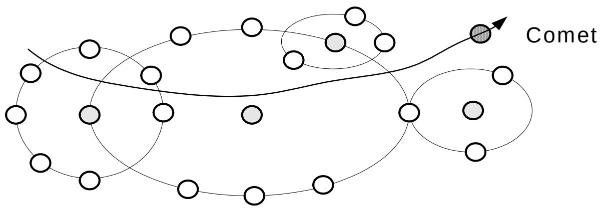

Figure 2.15. A so-called planetary organization (Ottosson 1999D)

In order to increase information flow further, there is a special role called a *comet*. The *comet* that should be an experienced, skilled, and mature person, has a special supportive function in a planet organization. The comet moves freely about, giving support where needed, and facilitates extra information flow between planet systems. A comet reports to the central sun. In a corporation, that sun would be the managing director or president.

Somewhat similar, but not so advanced models can be found elsewhere (e.g. Highsmith 2004 p240, Jaques and Clement 1994 p262).

2.6. Conclusions

The common PD methods differ as regards scope. SE and CE start with a *need* and are concerned with merging design efforts with production planning and preparation, making up what could be called limited methods as they disregard aspects of sale, organization (the human factor), and marketing, which are aspects that are treated by other methods. SE and CE cut in when a business case has already been established and can therefore sometimes have, as they require, stable conditions.

The same can be said of IPD, although IPD in their two original flavors are more extended methods as they both include a progression in time of market, product, and production factors, from identified customer need to sale. However, IPD according to Olsson (1985) includes organization, while IPD according to Andreasen and Hein (1987) include sales as a last activity (figures 2.6 and 2.7). IPD starts with a thorough market investigation and quality function deployment (voice of the customer, etc) as a basis for an elaborate product specification that must remain stable throughout the development project.

Stage-Gate™ (SG) is more of a scheme for upper management control of development projects, than a development method. However, at gates subjects are brought up in sequence starting with an idea-screening gate, proceeding with stable conditions and finishing with product launch. Sale is not included and SG has been criticized for not including idea generation.

IPE, like SE and CE starts with a *need*, then include design, and production aspects, but goes further and includes organization and some market aspects and allegedly handles unstable conditions.

All of SE, CE, IPD, and SG require stable conditions, and can be likened to machines in their rigidity. IPE is more flexible, while DPD is fully dynamic incorporating all aspects from *wish/want* to sale and production, relying on a learning strategy, as opposed to other methods. Further, DPD is directed at both PD and NPD, as opposed to other methods that start with a *need* and are more directed towards PD or reengineering.

Table 2.2 shows a deeper comparison between the different PD methods.

	SE	**CE**	**IPD(O)**	**IPD(A)**	**SG**	**IPE**	**DPD**
Wish/want	–	–	–	–	–	–	✓
Need	✓	✓	✓	✓	✓	✓	✓
Market	–	–	✓	✓	✓	(✓)	✓
Design	✓	✓	✓	✓	✓	✓	✓
Production	✓	✓	✓	✓	✓	(✓)	✓
Organization	–	(✓)	✓	–	–	✓	✓
Sales	–	–	–	(✓)	–	–	✓
Stable conditions	✓	✓	✓	✓	✓	(✓)	–
Planning strategy	✓	✓	✓	✓	✓	✓	–
Learning strategy	–	–	–	–	–	–	✓
PD	✓	✓	✓	✓	✓	✓	✓
NPD	(✓)	(✓)	–	–	(✓)	(✓)	✓

Legend: IPD(O) = IPD according to Olsson (1985), IPD(A) = IPD according to Andreasen and Hein (1987).

Table 2.2. Comparison of PD methods

3. The complexity of product development

In the preceding chapter on product development, when describing DPD, several references were made to complexity theory in connection with teamwork, as well as to strategy and maneuver thinking. It was even said that DPD could be seen as maneuver thinking applied to product development. Therefore, a brief description of these subjects as they apply to product development is given in this chapter, starting from a historical mechanical view and progressing into modern theories forming a new complexity based paradigm.

We have a progression from abstract and generic to concrete and special that looks like this (Richards 2004):

Culture ➔ Strategy ➔ Plans (tactics) ➔ Work (techniques are applied)

Culture determines what strategies are possible or acceptable. Then plans are born out of accepted strategy. Plans are transformed into work. It follows that our culture, our outlook, our view of the world is important for the way we perform product development. However, this paradigm, or worldview, this "Weltanschauung", can be a treacherous thing because it is invisible to us unless we actively question our paradigm.

3.1. The assumption of order

Humans are through action of their genes born with innate abilities. The brain has special audio, language, and vision processing circuits, an ability to sense probabilities and to do simple arithmetic calculations. Humans are born with not so simple abilities in psychology, and more simple ones in mechanics, physics, and engineering, etc. Further, humans appear, because of their brain's innate design, to prefer to see the world as, or assume that the world is, linear, ordered, and with simple causation (Pinker 2002).

The assumption of an underlying order that constitutes the world, can be seen from earliest recorded history, and early myths such as the Book of Genesis (Eden was a garden and God was a gardener), as well as in the Babylonian myth of creation (Kurtz and Snowden 2003), in Hinduism (Ross 1973), and in the Nordic myths (Crossley-Holland 1983). This assumption of order probably goes back at least to the dawn of agriculture (Brody 2000), when people depended on their ability to keep track of and foretell the shifting seasons.

In medieval times, there was the harmony of the spheres, and later when the heliocentric worldview became dominant, there was in the celestial mechanics of Isaac Newton, ordered motion. God was a watchmaker. Not long ago society also, was thought of as having a natural order with God on top, followed by the king, etc. Maybe it is comforting to think of the world as ordered and, perhaps, purposive.

Scientists by taking apart "Gods creation" (reductionism), could learn how the Great Watchmaker had designed nature, the machine, and what parts it consisted of. Through this knowledge, they would master nature. The world was perceived as knowable and became predicable, linear, and possessed simple causation.

3.2. Man's liking for designing machines

From earliest time humans seem to have had a liking for making tools and later machines to enhance the ability of the body (bows and arrows, trebuchets, windmills, waterwheels, etc) and mechanical devices to help with arithmetic operations and thereby relieving from tedious intellectual work.

A machine processes input and delivers output in a predetermined, rule based and foreseeable fashion. (There is no judgment at hand. All thinking and design has been done beforehand and laid down in "mechanical patterns"). In the same way, also bureaucracies are machines, designed that way for a purpose. Bureaucracies by their procedures and regulations save us from intellectual work. We eagerly remove human judgment by aid of a machine if it saves us from mental effort. "We use intelligence to structure our environment so that we can succeed with less intelligence" (Clark 1997). Other benefits we draw from such action are the predictability and quality control that are available to organizations designed to be machines (Morgan 1998).

The organization as a machine is designed as a rational structure of jobs and activities. Its drawing is the organizational chart and employees are hired to operate the machine and everyone is expected to behave in a predetermined well-defined way. This has the advantage of letting all organization members know what is expected of them. But it also lets them know what is *not* expected of them. Initiative is discouraged because people are expected to obey orders and keep their place, not to question what they are doing. This way of organizing creates rigidity that prevents organizations from adapting and flowing with change.

Examples of organization machines are insurance companies processing insurance claims, government processing taxes, and not long ago banks and others trading stocks and bonds. Even fast-food restaurants operate with every action predetermined in a minute way, even in areas where personal interaction with others are concerned. They are designed like machines, and their employees are in essence expected to behave as if they were parts of machines.

> "When we talk about organization, we usually have in mind a state of orderly relations between clearly defined parts that have some determinate order. Although the image may not be explicit, we are talking about a set of mechanical

relations. We talk about organizations as if they were machines, and as a consequence we tend to expect them to operate as machines: in a routinized, efficient, reliable, and predictable way" (Morgan 1998).

Machines of all kinds are a result of, and harmonize with human nature and therefore are hard to argue against in those cases where it is more efficient not to take to machines. We are so used to and like so very much to create machines that when judgment and creativity is called for, we often have a hard time leaving the machine thinking out of it.

It is understandable if scholars in the field of product development want to design machines and undoubtedly, literature is full of diagrams with rectangles and arrows describing some process thought out by some researcher. Precisely as with the designed machine-like organization, it is common in product development literature to find the opinion that before start, plans should be drawn up and subsequently followed. First, someone thinks and designs the project, team, planes, etc, and then the team carries out the work by realizing the plan through the execution of prescribed and preplanned procedures.

It is worthy of note to point out that the author is not trying to discredit the science of machine elements and other sciences that support engineering design. These sciences are very much about designing "machines" in the sense that the researcher designs an algorithm or schema to follow for dimensioning machine elements such as cog wheels, brakes, bolted joints, etc (e.g. Tepper and Schopf 1985, Beitz and Grote 1997).

Machines work best when there is a straightforward and well-defined task to perform and the environment is stable and predictable. They are good for producing exactly the same product repeatedly with precision and efficiency. However, machines can only solve "old" problems since all thinking is abolished and substituted for fixed rules. This makes machines rigid, unable to adjust to changing circumstance. However, to upper management this is often seen as a low price to pay for the control, and predictability, that is typical of a machine process. This false feeling of power reduces anxieties, which is especially important for authoritarian managers (Dixon 1994). So in this case, by adopting a rigid machinelike product development strategy/method, management kills two birds with one stone; the enjoyment of designing machines and the reduction of anxiety.

The strengths and weaknesses of machines are well matched to industrial production but less so to organizations such as product development teams or research groups, because in these cases the very nature of the work itself is opportunistic, demanding flexibility and an ability to utilize fleeting opportunities. The fact that Taylorism is so favored by upper management even in these cases indicates that: "Taylorism is as much a tool for securing general control over the workplace, as it is a means of generating profit. …One of the great attractions of Taylorism rests in the power it confers on those in control" (Morgan 1998).

Linear thinking (assumption of an ordered world, etc) is an innate human characteristic that can only be removed through education in appropriate sciences (Pinker 2002) and therefore one would expect not to find this paradigm governing theories of product development. Yet, linear thinking seems to be prevalent in this field. This is a bit strange since every engineer knows that the world is non-linear: oil viscosity is a non-linear function of pressure and temperature, the strength of metals depends on deformation speed and temperature in a non-linear way, no spring is perfectly linear, no material is stress free, machine elements can have strong non-linear characteristics, etc.

However, by an idealization of the world in which matter has linear characteristics and by just studying small perturbations about an equilibrium, the theory of elasticity and particle and rigid body mechanics, the study of small vibrations, etc, have allowed engineers and society to make tremendous achievements that perhaps have blinded us to the fact that linearity does not exist in nature.

Let us close this section by looking at an illustrative example. Assume that you know your start and final positions. For example, you might be standing outside the railway station in a foreign city with a piece of paper with the address to where you are going. To find your way, you call your host for directions. In this case, you know your present position and your final position, which are fixed. This is stable conditions. You are given directions: go straight north for about 500 meters to a crossing, take the road to the left, etc. A machine could have solved this problem, which is exactly as when a plan is seen as a timetable and precisely followed.

Now assume that you are in the middle of nowhere, completely lost and with no one to ask. Your position is unknown and your final position is undetermined, just somewhere civilized where there are humans that can help you. Now what do you do? This is unstable conditions and you have no preplanned way to follow. One solution could be to walk until you find running water. Then follow that water downstream until you come across humans or facilities that allow communication. In this later case a rule, or principle, was applied under unstable conditions, resulting in a unique non-preplanned route. The map was drawn in parallel to action, not beforehand. Only afterwards could one discern a pattern.

The later case is typical of new product development, while the former case is typical of industrial production or product development of the reengineering type.

3.3. Complexity

Although the French mathematician and physicist Henri Poincaré more than a century ago identified systems sensitive to initial conditions, which typically are associated with deterministic chaos, it was with the advent of computer simulation in the 1960s and 1970s, and especially agent-based simulations that everything changed (Solé and Goodwin 2000). The study of ecological and social systems, theoretical physics (non-equilibrium systems) and the comparison with computer simulations, has yielded exceptionally interesting results that have not yet reached a broader audience but is beginning to cross the border to other scientific fields.

C*omplexity theory* or *complexity science* is used as a unifying name for a set of patterns found in the most different areas and for the implications of these findings. The prevalence of them makes some theoretical physicists call complexity something more basic than physics (Buchanan 2001). "It may be that the complexity sciences will emerge as the dominant force, distinct from the older competing paradigms" (Mathews et al 1999).

In social sciences, complexity science was at first used as a source for metaphors, which has a value in itself (Lissack 1997). Organizational science has had difficulties handling nonlinear phenomena and has treated them as if they were linear (Andersson et al 1999). The application of complexity theory to organizations is justifiable since organizations and complex systems are not different phenomena (Maguire and McKelvey 1999). Organizations are complex systems (Dooley and Van de Ven 1999).

McKelvey's (1999) application of complexity science simulation[17] to organization science, and the view of Anderson et al (1999), highlights the importance of focusing on individual behavior instead of average behavior when analyzing complex systems. Jönsson (2004) has shown the importance of this conclusion in a large investigation at NedCar BV in the Netherlands. One interpretation could perhaps be that this indicates a superiority of the qualitative research method and case studies over the by necessity averaging quantitative methods of questionnaires and structured interviews.

3.3.1 Complexity and complex systems

One definition of complexity is as follows: *Complexity is the property of a real world system that is manifest in the inability of any one formalism being adequate to capture all its properties* (Mikulecky 2001). Another definition/description of complex systems is: *a system that is comprised of a large number of entities that display a high level of nonlinear interactivity*. There are a number of basic observations that have been made through the examination of complex systems, primarily using computer simulation and the mathematics of non-linearity (Uden et al 2001).

[17] Such simulations often consist of the application of a few simple rules on a large set of agents for many consecutive time steps resulting in intricate and unforeseeable patterns with striking similarities to observed phenomena in the real world, e.g. bird flocks, fish schools, Army ants, traffic, neural activity, spreading of disease, and forest fires.

- Complex systems are usually open systems (McKelvey 2004).
- Complex systems are incompressible, which means that it is impossible to have a total account of a complex system that is less complex than the system itself without losing some of its aspects. Incompressibility is probably the single most important aspect of complex systems when considering the development of any analytical methodology, or epistemology, for making sense of such systems (Cilliers 1998, 2005).
- Complex systems consist of a large number of dynamically (and usually non-linearly) interacting non-decomposable elements (McKelvey 2004).
- The interaction in a complex system is fairly rich (McKelvey 2004) and must be such that the system cannot be reducible to two or more distinct systems (Cilliers 1998). However, there can exist quasi-independent and emergent domains.

Because of high interconnectivity between elements, it can often be difficult to associate effect with cause. One is confronted with incredibly intricate interacting networks of cause and effect, rather than the relatively easily identifiable chains of cause and effect apparent in complicated, or linear, systems. These rich and pervasive dependencies place fundamental limitations on our abilities to develop and validate appropriate models of complex systems (Uden et al 2001).

- The interactions usually have short range and contain feedback loops (Cilliers 1998), and they may occur on several levels (Kolenda 2003).
- The behavior of the system is more determined by the nature of the interactions, than by what is contained within the components (Cilliers 2005). An example of a complicated (not complex) system (but never the less illustrative), from Polyani (1958) cited in Lichtenstein (2000): "Take a watch to pieces and examine, however carefully, its separate parts in turn, and you will never come across the principles by which a watch keeps time".
- Complex systems can have an adaptive capability to influence, almost control, their environment and re-organize their internal structure without the intervention of an external agent. Such systems are called complex adaptive systems (CAS). Often the agents making up the CAS are adapting individually, each applying their own strategy (Axelrod and Cohen 1999). Examples of CAS are free-market economies (Englehardt and Simmons 2002, Stamps 1997).

Human organizations are often considered to be CAS (Dent 2003). In several aspects, human organizations differ from other complex systems, such as bird flocks, fish schools, and ant colonies. Humans have the ability to comprehend at least some of the consequences of the system. Further, humans as agents of CAS are affected by emotions such as compassion and anxiety; they are capable of prioritizing their own mental objectives over those of the group; they are aware and capable of thinking systematically, unlike most other animals and all insects; and power differences exist between agents, by which they are influenced. Consequently, these complex human systems are still more complex (Chiva-Gomez 2004).

- Complex systems operate under conditions far-from-equilibrium (McKelvey 2004).
- Complex systems have a history (Buchanan 2001, Cohen 1999, McKelvey 2004, Richardson 2005, Cilliers 2005). The system memory and history is captured at both the micro- (personal experience, personal opinions, worldview) and macroscopic (cultural, ritual, value system) levels. Therefore, system history plays an important role in defining the state of the system as well as affecting system evolution (Cilliers 1998).
- Each element in the system is ignorant of the whole (McKelvey 2004).

The ignorance of the whole is not necessarily true for systems comprising human agents who might each have their own view of the system, its purpose, and direction, leading to political activities. This awareness of the system's direction is the reason why complex human systems can be purposefully influenced. However, attempts at governing complex systems can yield unexpected results. It was for a long time assumed that systems could be controlled, when in fact they can only be influenced (McElyea 2003, Olson and Eoyang 2001). When modeling human systems, it is done from an outsider perspective, but for the modeling to be useful, it is important to use ones imagination in order to see what the modeled interactions are saying from within that interaction (Stacey 2002, p71).

- A complex system might react proportionately to small as well as large changes; it might also react disproportionately to both small and large changes. It might be very sensitive to initial conditions (a phenomenon popularly referred to as deterministic chaos) as well as at times, be very resilient and insensitive to initial conditions (as a result of self-organization or, alternatively, antichaos[18]) (Uden et al 2001, Richardson et al 2000).
- A complex system, driven to critical state, edge of chaos, has its own highest computational capacity (Langton 1990). This means that the system cannot be simulated with sufficient accuracy faster than the system itself develops. Such a system can be completely deterministic, yet completely unpredictable.
- Complex systems can show **emergence**, which are unexpected, often unpredictable characteristics of the system that are a result of interaction be-

[18] Antichaos is a term for essentially self-organization coined by Kaufmann (1991).

tween the elements of the system. An example: electrochemical activity in the brain results in consciousness. Micro level interactions between individual agents and global, aggregate-level patterns and behaviors mutually reinforce each other (Linstone 1999).

- Self-synchronization leads to emergent properties and efficiencies unattainable with top-down direction (Wesensten et al 2005).

An example of such system-wide self-organization can be found in flocks of birds, where there is no single, organizing, bird leader. Nevertheless, a pattern of organization develops from local interactions among agents following simple rules. The benefit of self-organization is a structure that is fluid and sensitive to the needs of connected elements. Self-organizing behavior is disorderly only by traditional management standards, because patterns of behavior and decisions emerge rather than result from specific plans (Ashmos et al 2000):

- Complex systems show existence of a rich diversity of qualitatively different operating regimes that the system might adopt.
- At the basis of a complex system, there can be a few simple rules.
- Complex systems often have network character.
- Complex systems can be unpredictable at one level, but strikingly predictable at another (weather as opposed to climate).

A complex system may favor one or several areas of its state space, called an attractor, where the system appears to be locked-in for some time. Examples of attractors in a human system are habits, traditions, and culture. It may require a substantial perturbation of the system for it to move out of an attractor, perhaps only to be locked-in by another attractor (Lewin 2001).

3.3.1.1 Complex systems and power laws

Many phenomena in the most apart situations and especially complex systems, exhibit a power law $\mathbf{y = ax^n}$ behavior. Plotted in a log-log diagram a power law is a straight line with slope $\mathbf{n}$. If $n < 0$ the number of occurrences are inversely proportional to the size of the occurrence; many small and few large occurrences. Some such examples are number vs. size of movements at the stock exchange (Sornette 2001), number vs. mass of individuals in a biotope (Buchanan 2001), and number of links pointing to a website vs. number of websites (Barabási 2002).

Power laws have the following especially fantasy stimulating characteristics:

- There is no typical size; the process is scale free.

- Similar occurrences of all sizes are just as natural and are basically of the same origin if they belong to the same power law (the same exponent).
- It is impossible to predict if an occurrence that is governed by a power law will be large, small or medium, making prediction virtually impossible.

The processes are rooted in a kind of geometrical relation between the elements. How the elements influence each other over distance is important. Sometimes an element may influence many other elements and sometimes only a few. The elements are members of a network with links of varying strength (Watts 1999, Barabási 2002, Buchanan 2001).

The study of complex systems that exhibit power law behavior has shown that the future development of the system is dependant on the way the system arrived at its present state. History is baked into the present and can function as trigger points for often unthinkable chains of events.

The system may drive itself to criticality, the "edge of chaos". For example, all living species use their biotope to the limit and beyond. In nature, there is no holding back or economizing with resources, resulting in eternal crisis. Often only one species becomes extinct at a time, but about every 200 million years or so global ecosystems break down and we have mass extinction of species of exactly the same causes as when just one or two become extinct (Lewin 1999).

It is common to think that big events must have important causes. However, even the largest occurrences may have the smallest origins. Furthermore, many behaviors in the social world might be explained with a natural "scale-free" generating mechanism (Dooley and Van de Ven 1999).

3.3.1.2 Complexity thinking

The *Complexity thinking* school of thought takes hold of the fact that no real complex system is completely closed; all complex systems are more or less open, and therefore they stress the following points as limitations to our ability to know for sure (Richardson 2005):

- All boundaries are emergent and temporary (given a sufficiently long time scale), neither purely natural nor purely a function of our description, sometimes making boundary recognition and allocation problematic. Boundaries in the rigid traditional sense do not exist. The boundaries analysts infer around a system are more a feature of our need for a bounded description rather than a feature of the system itself (Uden et al 2001).
- Everything is connected to everything else – radical holism: the universe is the only true whole.

- No part can be ***fully*** understood without understanding its relationship with the whole, the whole is reflected in every part and all models leave something out.
- Absolute knowledge of the part would require complete knowledge of the whole (the incompressibility of complex systems) – a practical absurdity and a theoretical impossibility.
- There are no real parts; all boundaries that delimit a part from its whole are temporary and often illusory: no-boundary hypothesis, all boundaries are emergent

In spite of the epistemological caveats from the complexity thinking school, for practical purposes it is useful to define boundaries and treat organizations as open complex systems, thereby disregarding the errors and approximations with such an approach (Cilliers 2005).

3.4. Organizations as complex systems

The field of organizational application of complexity science has emerged in the past ten years (Eoyang 2004). It is increasingly used by researchers and practitioners to improve their understanding of organizations (Chiva-Gómez 2003).

One purpose of organization science is to facilitate design, or in other words, to change and improve upon organizations. One aspect is the fit between the organization and its environment achieved through *evolution and adjustment*. Many researchers therefore study this aspect (Levinthal and Warglien 1999, Morel and Ramanujam 1999, McKelvey 1999, White et al 1997). In this regard, it is convenient to *see the organization as an organism that survives by continuous adjustment to its environment*. If the organization is an organism or a collection of organisms then *the environmental assessment must be a critical focus for long-term survival and success* (McElyea 2003).

Complexity science has been applied to the study of "the normative order, operating through informational and social influence that guides and constrains people in collectives", which is culture (Frank and Fahrbach 1999) and can be extended to a whole society as in understanding western firms in China (Boisot and Child 1999). Some researchers try to understand the character of organizational dynamics through event time-series analysis (Dooley and Van de Ven 1999). However, foremost complexity in connection with organization sciences is used for theories of change management (Higgs and Rowland 2005, Eoyang 2004, McElyea 2003, Styhre 2002, Ashmos et al 2000, Beeson and Davis 2000, Zimmerman and Hayday 1999). See table 3.1 for a comparison of traditional vs. complexity-based ideas of change management.

Traditional Models of Organizational Change	Complex Adaptive Mode of Organizational Change
Few variables determine outcome	Innumerable variables determine outcome
The whole is equal to the sum of the parts (reductionism)	The whole is different from the sum of the parts (emergence)
Direction is determined by design and power of a few leaders	Direction is determined by emergence and the participation of many people
Individual or system behavior is knowable, predictable, and controllable	Individual or system behavior is unknowable unpredictable, and uncontrollable.
Causality is linear: every effect can be traced back to a specific cause	Causality is mutual; every cause is also an effect, and every effect is also a cause
Relationships are directive	Relationships are empowering
All systems are essentially the same	Each system is unique
Efficiency and reliability are measures of value	Responsiveness to the environment is the measure of value
Decisions are based on facts and data	Decisions are based on tensions and patterns
Leaders are experts and authorities	Leaders are facilitators and supporters

Table 3.1. Traditional vs. complex organization change (Olson and Eoyang 2001)

In the complexity view of organizational change the system is far from equilibrium, it dissipates energy (imports matter, energy, and humans (Reynolds 2004)), it is self-organizing, capable of radical transformation as well as gradual evolution, and continually moving between order and disorder as well as between stability and instability.

Processes are *irreversible and cannot be fully controlled or planned* (Beeson and Davis 2000). Informal structures (the shadow system) self-organize, emerge, and persist in a way that is remarkably robust to changes in the formal organizational structure (Anderson 1999). Organizational development practitioners should *intervene in the shadow organization* (Dent 2003), because it is here that self-organization is primarily to be found.

3.4.1 Organizations can be teleological

White et al (1997) propose that organizations in their evolution are formed not only by environmental selection but also by the organization's own choice of path, perhaps from among several viable internal evolutionary drivers. Mikulecky (2000) claims that the system has within itself a model of its environment that it uses to influence present behavior in anticipation of future events. The members of the organization take actions they feel will move towards desired futures. The organization is thus at least partially a product of human intention, as a complex creative adaptive system (Rowland 2004).

Buckle (2003) takes this idea further. Organizations are teleological, purposive, designed to achieve predetermined goals. This they do by using organizational knowledge, which includes both conscious and unconscious dimensions. There is for instance tacit knowledge, which is unconscious, but still can be highly goal directed. This duality of knowledge applies also to organizational teleology since organizational behavior unfolds in service to consciously understood teleological aims (such as corporate strategies and business plans) and to unconscious teleological aims (that are un-designed or emergent), which are subtler to detect.

Many of the intentions driving organizational behavior are publicly understood and sanctioned; others are less well understood and unsanctioned. To the degree that some purposive behaviors in organizations remain unconscious, it may detract resources from managerial objectives and confound organizational change efforts regardless of the desires of any one manger.

3.4.2 Self-organization and emergence

Self-organization, which is the spontaneous generation of system-wide order in a complex adaptive system, and emergence, which is the spontaneous creation of new entities or patterns in a system through self-organization, are two aspects from complexity science that are especially important for organizations. However, until recently the power and ubiquity of self-organization was not understood.

Eoyang (2004) gives a theory of self-organization in human systems. According to this theory, self-organization requires three interdependent conditions: *container, significant difference,* and *transforming exchange*. A change in one of the conditions results in a change in the other two.

Container is a name for the boundary that distinguishes a self-organizing system from its environment. There are three basic containers that each constitutes a condition that pulls individuals tighter and increases the probability for self-organization.

1. External boundary or fence: a room, information system, membership criteria, etc, constraining the agents into a shared space.
2. A central attracting force: a magnet, e.g. a charismatic leader, a clear and shared vision, and a desirable resource.
3. One-to-one attractive forces, affinity-like containers: e.g. gender, ethnic identity, shared language, and trust.

Significant differences. Within a container, difference along one or several dimensions between agents establishes a potentially generative tension. These can be power, money, experience, language skills, etc.

Transforming exchange. Language is the most obvious manner of transformative exchange, but any transfer of information, energy, or matter can function. The exchange becomes transforming when it affects the self-organizing processes within the agent, crossing containers from system of agents to the agent as a system.

The system has self-organized when stable system-wide patterns are maintained for some time. Internal dynamics might hold the system in a stable state by opposing change or emergence of new order. This is called **coherence** and is characterized by:

- Meaning is shared among agents
- Internal tension is reduced
- Actions of agents and sub-systems are aligned with system-wide intentionality
- Patterns are repeated across scales and in different parts of the system
- A minimum amount of energy of the system is dissipated through internal interactions
- Parts of the system function in complementary ways.

Further, according to Eoyang (2004), system-wide coherent patterns are more stable than other self-organized patterns. Because of the mutually reinforcing dynamics, the effort required to change the pattern is greater than the effort to maintain it. When the system reaches a state of coherence, the available energy of the system is aligned and focused on system-wide behaviors, rather than diverse and disruptive behavior of individual agents or sub-system clusters.

Interventions that increase the coherence of one level of the human system increase the effectiveness of that organizational level.

As an aid in understanding the degree of difference in an organization, Eoyang (2004) designed a so-called difference matrix, table 3.2.

	High difference	**Low difference**
High feedback	Contention Disagreement New learning Shared understanding	Singing to the choir Little new productivity Comfortable Reinforcing
Low feedback	Avoidance Fear and anxiety Individual reflection Safety	Boring Entropic Passive Quiet

Table 3.2. The difference matrix, from Eoyang (2004)

It can be seen that intense development (upper left corner) goes hand in hand with disagreement and anxiety, but can also result in a shared understanding. The comfortable, reinforcing zone (upper right corner) is not very creative.

3.5. Order and un-order

This section is based on an article by Kurtz and Snowden (2003) in which they give a model for organizational regimes of operation based on several years of action research into the use of narrative and complexity theory in organizational knowledge exchange, decision-making, strategy, and policy-making in among others, product development, market creation and branding. They base their analysis on what they say are three universally accepted assumptions *that they question*:

The assumption of order, which states that there are underlying relationships between cause and effect in human interactions and its consequence: that it is possible to produce prescriptive and predictive models and design interventions that allow us to achieve goals.

The assumption of rational choice states that humans will make a "rational" decision based only on minimizing pain or maximizing pleasure. Consequently, their individual and collective behavior can be managed by manipulation and by education to make those consequences evident.

The assumption of intentional capability meaning that the acquisition of capability indicates an intention to use that capability, or stated differently: that all actions are intentional and have a premeditated purpose. It is important to refute this assumption because it is only possible to consider alternative explanations for actions when one relaxes the assumption that all actions are deliberate.

Humans are not limited to one identity. In a human complex system, we constantly flex our identities both individually and collectively. We may be child, parent, spouse, etc, and belong to shifting groups and change our behavior depending on context, something that is very difficult, if not impossible, to simulate. Further, humans are not limited to acting in accordance with predetermined rules. We are able to impose structure on our interactions as a result of collective agreement or individual acts of free will. As a result, questions of intentionality play a large role in human patterns of complexity. This also is difficult to simulate.

Within a rule-based simulation it is difficult to simulate free will and complex intentionality, e.g. retrospective elaboration, duplicity, groupthink, rumor, self-deception, manipulation, surprise, confusion, internal conflict, stress, changes in the meanings of previously unambiguous messages, the deliberate creation of ambiguity, inadvertent disclosure, charisma, cults, and pathologies.

Humans are not limited to acting on local patterns. People have a high capacity for awareness of large-scale patterns because of their ability to communicate abstract concepts through language and over large distances because of the technological infrastructure. This means that to simulate human interaction, all scales of awareness must be considered simultaneously rather than choosing one circle of influence for each agent.

Acknowledging the complexity of human organizations, but refuting computer simulations, Kurtz and Snowden (2003) create a novel distinction; that between order and, what they call un-order. Systems can be either ordered or un-ordered. In fact, they say that: "…learning to recognize and appreciate the domain of un-order is liberating, because we can stop applying methods designed for order and instead focus on legitimate methods that work well in un-ordered situations". For instance in dynamic and constantly changing environments, it can be possible to pattern un-order but not order.

In an ordered environment, one can rely on and act-out entrained patterns based on passed experience, in an un-ordered environment that could be fatal. These two areas are each further divided into two parts. The complex system is thus seen as comprised of four parts, where the great divide is between order and un-order, figure 3.1.

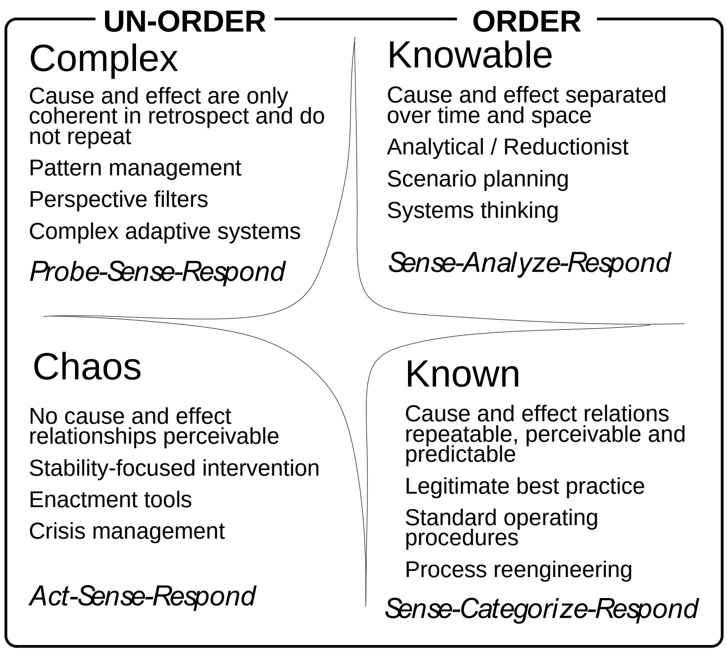

Figure 3.1. The Cynefin framework for organizational sense making, from Kurtz and Snowden (2003)

The four corners represent the extreme values of respective domain and the four-armed figure in the middle separating the domains represent a divide or no mans land between them. Kurtz and Snowden call this the Cynefin[19] framework and primarily use it for sense making in organizations.

[19] The Welsh word Cynefin is properly understood as the place of our multiple affiliations.

It is important to note here that "known" and "knowable" does not refer to the knowledge of individuals but to things that are known to society or the organization.

Ordered domain: Known causes and effects. Cause and effect relationships are generally linear, empirical in nature, and not open to dispute. This is the domain where process reengineering and optimization is straightforward. The focus is on efficiency, single-point forecasting and field manuals. The decision model here is to sense incoming data, categorize that data, and then respond in accordance with predetermined practice.

Ordered domain: Knowable causes and effects. Stable cause and effect relationships exist, although they may be separated over time and space in chains that are difficult to fully understand, making them not fully known, or known only by experts. *Everything in this domain is capable of movement to the known domain.* The issue is whether one can move from the knowable to the known by oneself. Often we cannot and instead rely on experts. *Here the entrained patterns are at their most dangerous*, as a simple error in an assumption can lead to a false conclusion that is difficult to isolate and may not be seen.

Un-ordered domain: Complex relationships. *Emergent patterns can be perceived but not predicted*; this phenomenon is called *retrospective coherence*. Structured methods that seize upon such retrospectively coherent patterns and codify them into procedures will confront only new and different patterns for which they are ill prepared. Thus, relying on expert opinions based on historically stable patterns of meaning will insufficiently prepare us to recognize and act upon unexpected patterns.

Understanding requires multiple perspectives on the nature of the system. This is the time to pay close attention, gain new perspective on the situation, and think before one acts. The methods of the known and knowable domains do not work here but narrative techniques are particularly powerful.

Un-ordered domain: **Chaos**. There are no perceivable relations, no visible relationships between cause and effect. There is no time to investigate change, analyze, or wait for patterns to emerge.

The domain of disorder (the area within the central four-armed figure). The central domain of disorder is critical to understanding conflict among decision makers looking at the same situation from different points of view (from within different domains). Often people agree on what the extremes of the four domains mean in the context they are considering, but disagree on more subtle differences near the center of the space. As a result, individuals compete to interpret the central space based on their preference for action. The stronger the importance of the issue, the more people seems to pull it towards the domain where they feel most empowered by their individual capabilities and perspectives.

Boundaries are possibly the most important elements of sense making, and especially the crossing of boundaries. A boundary might look different depending on from what direction it is approached. Important here is awareness of approaching the boundary, so that one can sense when change is incipient and respond before the boundary is crossed (perhaps to cross it purposefully, perhaps to avoid it), and of crossing the boundary, so that one can respond quickly to new conditions after one has arrived on the other side. It may be possible to manage the boundary and the perceptions surrounding it, so that one, for example, can put a deep chasm boundary in place for one's adversary while maintaining a shallow -river boundary for one's own use.

There are many possible paths within the Cynefin framework, figure 3.2.

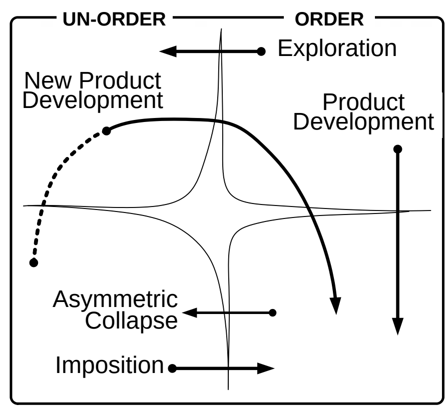

Figure 3.2. NPD and PD pathways applied to the Cynefin framework

Asymmetric collapse is the movement from the known to the chaotic in a disastrous way. This mode is typical of organizations that settle in an environment and fail to observe that circumstances have changed, until it is too late. Some organizations tend to oscillate between known and chaos.

Imposition is the forceful movement of an organization from chaos to the known. This is often the result of asymmetric collapse, and typical examples are the regular reorganizations of large companies.

Exploration is movement from the knowable to the complex, that function as an opening up of possibilities by reducing or removing central control without a total disruption of connections.

An organization may exploit the shadow system. Self-organization also works on this informal system, which is very much intertwined with, yet constantly attempts to undermine, the legitimate hierarchy. Interactions in the shadow system are based on the free choice, preference, benefit, and self-interest of the agents, yet at the same time, these agents have their formal roles in the organization; these different roles are always co-creating and influencing one another (Aram and Noble 1999).

This requires careful monitoring and awareness of the shadow system. In most organizations, there is a strong and often untapped resource to be found in exploratory moves such as this. For example, informal communities, which may range from public to secret in their profile, provide a rich and fertile source of knowledge and learning that is too large and complex to be formally managed.

Product development (PD) is often thought of as only involving mechanistic adjustments and limited redesign of a product already in production. This is sometimes called reengineering. The path is from within the knowable and through development, the product moves down into the known domain.

New product development (NPD) is different. New product here means conceptually new to the design team, whereby they by necessity must go beyond an extrapolation of previous products, resulting in creative activities residing in the truly complex (Rose-Anderssen et al 2005). NPD may even start in the chaotic domain, but most certainly, for a large part resides in the complex. Consequently, NPD is difficult to manage. It has already been pointed out that established procedures may not work, historically stable patterns of meaning cannot be relied on, and expert opinions are insufficient or sometimes even false. The way to act is multiple thrusts, that is to create probes to make the patterns or potential patterns more visible before taking action. One can then sense those patterns and respond by *stabilizing those patterns that are desirable*. Understanding requires multiple perspectives on the nature of the system.

3.6. Emergent knowledge process, EKP

A new product development project, performed by a geographically dispersed team, has recently been reported (Malhotra and Majchrzak 2005, 2004, Sawy and Majchrzak 2004, Markus et al 2002, Malhotra et al 2001, Majchrzak et al 2000 A, 2000 B). The authors used a multi methodological approach attending all 89 virtual meetings, sending out weekly questionnaires, studying archived data files, and performed interviews.

The studied project comprised eight people: a project team leader, concept designer, lead engineer, combustion analyst, and thermal analyst from two different geographically separated organizations in Rocketdyne, a manufacturability engineer and a CAD (Pro-Engineer) specialist from Raytheon (then Texas Instruments) located 1,000 miles away, and a stress analyst from MacNeal-Schwendler Corporation, located 100 miles away (Malhotra et al 2001). This inter-organizational virtual team[20] developed over a 10-month period a novel rocket engine, while continuing their normal duties with their respective collocated teams, setting off only marginal time for the virtual team project. The team was by all standards extremely successful (Majchrzak et al 2000 A):

> “The team succeeded at designing a thrust chamber for a new rocket engine with only 6 parts instead of the traditional hundreds, with a predicted quality rating of 9 sigma (less than 1 failure out of 10 billion) instead of the traditional 2 to 4 sigma,

[20] A virtual team is a group of geographically and/or organizationally dispersed coworkers that are assembled using a combination of telecommunications and information technologies to accomplish an organizational task (Majchrzak et al 2000).

> at a first unit cost of $50,000 instead of millions, and at a predicted production cost of $35,000 instead of millions. The team was able to achieve all of this with no member serving more than 15% of his time, within the development budget, with total engineering hours 10 times less than traditional teams, using a new collaborative technology with several partners having no history of working together. The team members achieved this success through collaboration.
>
> The team received an award for outstanding achievement from RocketCo Senior Management".

The team had an html-based collaborative communication technology (CT) tool for communication, information storage and retrieval (organized database, keywords), whiteboard, sketching, etc, that was custom developed for the team. It was found however that the team made little use of the supposedly powerful organization search and retrieval mechanisms provided by the CT utility.

The reason for this was that ***the design process was so unpredictable*** (the team created over 20 different engine design concepts) that most of the members had no clue as to whether or not the knowledge they were putting into the database would be of value later on and thus those entries did not warrant attempts at categorization and organization. This was so in spite of the fact that very many entries were later referenced. When reference links were created, the team regarded this as the most helpful feature for finding information (Majchrzak et al 2000 B). The team never came to a conclusive design of the CT tool although no less than 23 versions were created and tried during the project (Malhotra et al 2001).

One reason for this is that creative work is substantially different from routine problem solving in many ways, for instance (Malhotra et al 2001):

1. Solutions are generated in *unpredictable* ways,
2. Both the analysis and the solution need to be generated *concurrently*,
3. The design process is a series of seemingly irresolvable tradeoffs, with *priorities* among tradeoffs *emerging as the design progresses* and the process gradually builds a consensus around the solution that meets these priorities,
4. Problems are often not well-specified, being understood only as they are solved,
5. Tasks cannot be easily apportioned to individuals since everybody makes an unpredictable contribution to the process (a true team effort),
6. *Expectations evolve* (rather than are found and followed) about the task, work, collaboration, context, jargon, and assumptions.

During the research of appropriate CT tools and researching how to design them, Markus et al (2002) discovered that the creative new product design activities they had witnessed in the rocket engine design team, from a knowledge management point of view, belonged to a new class of problems. They dubbed this new class *emergent knowledge process*, EKP.

Emergent knowledge processes are organizational activity patterns that exhibit three characteristics in combination:

- Deliberations with no best structure or sequence
- Highly unpredictable potential users and work contexts
- Information requirements that include general, specific, and tacit knowledge distributed across experts and non-experts.

Examples of EKPs include basic research, new product development, strategic business planning, and organization design.

Process has traditionally been described in terms of structure. However, in this case, increased structure is neither possible nor desirable, because it might introduce rigid, stereotyped responses where creativity and flexibility are needed. Such unstructurable processes have been referred to in terms of human sense making: building knowledge in a recursive, participatory, and evolutionary manner. Because the term *unstructured* suggests that structuring is possible and perhaps desirable, Markus et al (2002) instead elected to use the term *emergent* as a better label.

An example of an emergent process is new product development, which can be described as a series of unpredictable trial-and-error experiences in which the developer iterates recursively between problem-finding and solution evaluation.

In a later article Sawy and Majchrzak (2004) introduce the OODA-loop[21] and the necessity to increase decision speed and agility in a competitive business environment. They note that in the studied project the quick action-learning loops, where new designs were created from scratch each week, led to a process that was no longer able to follow a traditional product development process.

This quick iteration on the work process allowed the team to work in a way that encouraged quick iteration on the work product. Experts were called in on the spur of the moment, with each individual contributing his perspective on the situation. People acted before they were able to fully comprehend a problem. In fact, *they acted in order to understand the problem*, creating only partially predicable events, making problem definitions evolve. This was a real-time emerging knowledge process.

According to Sawy and Majchrzak (2004), key to the team's success was synergy between emergence of the work process and product, coupled with quick action-learning loops. According to them few people have the capability of functioning effectively in such teams: they require deep expertise, aptitude to function well under

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[21] For a description of the concept, see the following section on strategy.

stress, a quick ability to size a situation, the cognitive flexibility to completely adopt a new perspective, and ability to improvise as new knowledge is acquired.

3.7. Strategy

Companies compete on a market. The number of customers and their willingness or ability to purchase is limited. Such a situation, where we have competition for limited resources, where ones gain is the others loss, is called a conflict.

To survive it is important to handle conflicts successfully and come out of them as victor. The attitude, mindset, or methods for winning conflicts are the subject of theories of strategy, which no doubt have been mostly developed and tested in connection with warfare. Wars are unforgiving test beds and whatever strategies evolve from them probably have some degree of relevance also to other forms of conflict. Because, without knowing it, the military were operating complex organizations (Artigiani 2005).

Strategy has military roots. It has been found that strategies for armed forces will be most effective if they master the following concepts (Kolenda 2003):

1. *Decentralization:* create and exploit a knowledge advantage by empowerment at the appropriate levels.
2. *Complexity:* gain a complexity advantage by maximizing the number of meaningful interactions.
3. *Tempo:* sustain an intensity of operations over time with which the competition cannot cope.

One consequence of the results from complexity science is that we cannot be as sure as we previously thought that the future could be predicted. This uncertainty is not reducible to information: *perfect information will not remove uncertainty* (Artigiani 2005, Kolenda 2003). For example, the theoretical limit to weather forecasts is 3-4 weeks and will never be exceeded (Wiin-Nielsen1999).

Furthermore, very large and very small occurrences can have the same origin and it is impossible to predict, when they occur, if they will be of significance or not. The possibility to foretell the future is small and unexpected things can suddenly happen.

3.7.1 Planning

In an orderly world that is linear and proportional and where perfect knowledge is available, precise planning is possible, but in a complex world where order is circumstantial, any reliance on plans is rather futile.

Therefore, plans will not hold together, because the past, which plans are based on, is not an accurate compass for the future, but also because change is so pervasive that the environment can undergo profound alterations while the formal planning process is underway. But planning, never the less, is very important because (Cunha and Cuhna 2002):

1. During planning, management's discussion on possible future scenarios creates a "memory of the future" so that when circumstances unfold they are met with prepared actions (Bunker and Alban 1997).
2. A shared knowledge of plans may be used as a coordination mechanism for individual improvisation.
3. Plans can be conceived as actions unfold, making economizing with scarce resources easier.
4. The planning process can yield organizational learning, shared mental models, in fact a meta-language.

Separation between the observers and the planners (e.g. between first line operators in contact with customers/users and senior management) is a source of information filtering and delay, which can be dangerous in a fast paced environment (Cunha and Cuhna 2002). The solution is to merger action with planning, resulting in a bottom-up design more efficient than any top-down design (Wesensten et al 2005, Lewis 1994) and the basis for maneuver thinking.

The application of this idea to new product development could be thought of as reliance on self-organization (bottom-up) and a probe-sense-respond mode of operation (figure 3.1), which could also be described as quick iterations, or a process of evolve and adapt, and iterate (Highsmith 2004).

We must let go of the idea of the plan as a timetable, but utilize the other aspects of planning. Then to succeed, planners do not need to "know" the future. Because systems guided by rules for making rules are much more flexible than formal systems. Furthermore, if by a lively preparatory communication the organization's members have acquired a shared understanding of proper actions and shared mental models, then they can effectively think in one another's brains (Artigiani 2005).

3.7.2 Business strategy

In the business world, strategies are sometimes thought out based on an analysis of circumstances, strengths and weaknesses, etc, (Markides 2000), but more often, they are created because of adaptation to the environment, especially for small and medium sized enterprises (Rantakyrö 2004). In later years, business strategists have been looking at complexity science for metaphors and analogies (Englehardt and Simmons 2002).

The well-known case of IKEA is a good example of how a certain culture in combination with environmental necessities created a brilliant strategy. The following is from Markides (2000, p 150):

> When Ingvar Kamprad, IKEA's founder, tried to crack this market, he was shut out at every turn. Barred from selling directly at trade fairs, he resorted to taking orders there. When that was forbidden, he contacted customers directly (initiating a profitable mail-order business, which necessitated that the furniture be easy to ship). When Swedish manufacturers refused his business, Kamprad sourced from Poland, getting even better prices than before. Locked out of traditional outlets, Kamprad converted a factory into a warehouse and showroom, where explanatory tags, self-service, a colorful catalog, and the lure of instant availability—thanks to on-site stocking—were deliberately distinctive. In every instance, the strategy was driven as much by necessity as it was choice. . . . In hindsight, IKEA's positioning is indeed brilliant and is indeed a source of real and sustainable differentiation. The position, however, was as much a consequence of adaptability as it was of strategy. It was persistence—and experimentation under the strict discipline imposed by constrained resources—that allowed IKEA to build its furniture franchise.

3.7.3 Aim or purpose of strategy

> *The aim or purpose of strategy is to improve our ability to shape and adapt to unfolding circumstances, so that we (as individuals or as groups or as a culture or as a nation-state) can survive on our own terms.*
>
> *John R. Boyd*

The citation defines strategy according to USAF Col. John R Boyd, Korea veteran, creator of fighter aircrafts F15 and F16, and teacher at US Marines War College. Boyd created his theory of strategy after having studied 2500 years of human conflicts. Boyd never published his theory, but gave a number of comprehensive briefings that spread his ideas among strategists that have later published Boyd's theory (e.g. Richards 2004, Hammond 2004, Coram 2004).

The Boyd theory was primarily conceived for international politics and military conflicts. However, the theory is of a general nature and applies to all conflicts, where two or more parties compete for limited resources, and that makes the theory useable to those who lead organizations and/or develop new products.

Decisive for the outcome of a conflict is the ability to observe, orient, decide, and act quicker than the adversary. Especially important is the ability to shift orientation swiftly. The result is generic and applies to all systems: an individual, a project group, product developing company, or a nation.

The O-O-D-A-loop of John R Boyd (figure 3.3) is not a loop in the same way as for instance Deming's wheel in quality work that is run through step-by-step, revolution after revolution (e.g. Nyanchama 2005, Walley and Gowland 2004). Instead, there is a continuous Observation-Orientation with a Decide-Act when necessary. That is, a perpetual process of ongoing activities – not a cyclic development!

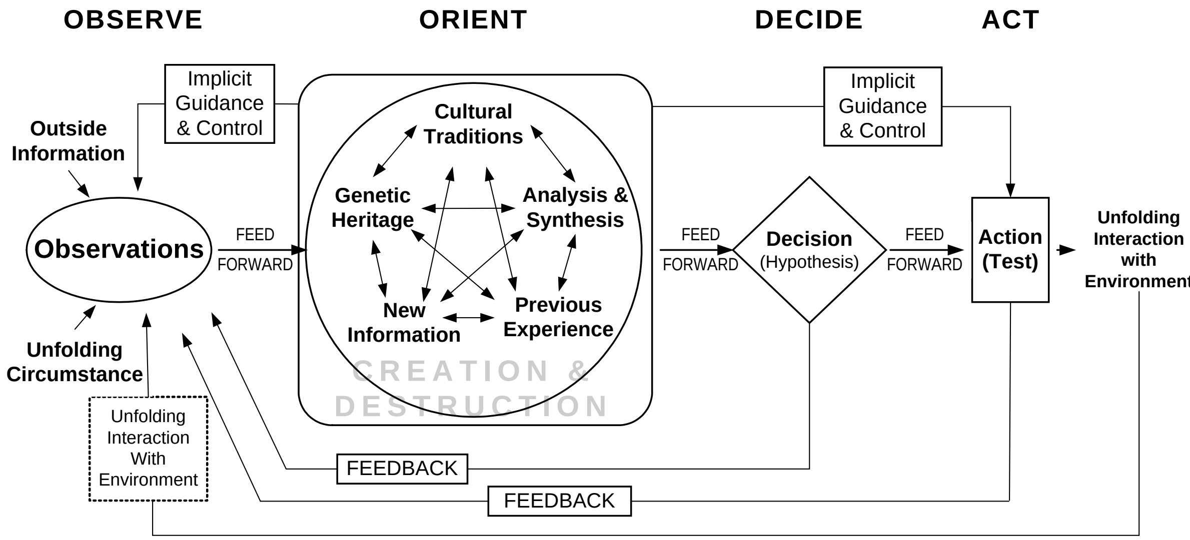

Figure 3.3. The Boyd loop (Richards 2004)

Observe (Richards 2004): One cannot observe without distortion, because what one observes (has the ability to observe), depends on the mental models that one possesses; how one is oriented. Therefore, our orientation decides what we observe. That for which one lacks concepts/mental models cannot be observed. What one try to observe is ever changing.

Orientation (Richards 2004) is adaptation to the observed reality. What we observe depends on our orientation, which in turn depends on genetic heritage, cultural traditions, earlier experiences, new information (if one has the ability to digest it), and analysis and synthesis of the situation at hand (to see that which can not be seen with the eyes).

Creation & Destruction (figure 3.3, Orient block) stands for the fact that one must destroy, abandon, a mental model for to be able to accept a new one (for the same set of facts). It can be very hard to break old, familiar patterns; especially if they have been internalized and thereby made unconscious to us. It is here that the greatest difficulties abound.

The idea that it is constructive to be able to abandon ones ideas is not new, as strategist Yagyu Munenori (1571-1646) talked about the necessity of not allowing ones mind to tarry (Yagyu 2000, Takuan 1987), and strategist Miyamoto Musashi (ca: 1585-1645) says: "It is a matter of harboring an open, free and fluid mind" (Musashi 2001).

Discussing successful designers, Lawson (1997, p 158) says: "Creative thinkers in general and designers in particular seem to have the ability to *change the direction* of their thinking thus generating more ideas".

Decide: Based on a hypothesis of reality and probable development, we make decisions that will affect the very reality that we observe (Richards 2004).

Act: Our actions influence, alter, the observed reality and thereby what we observe and how we orient. The orientation influences action, which is the realization of the decision, since our way of action depends on the same factors as our orientation: earlier experiences, cultural traditions, etc. We are for the most part unaware of these mostly subconscious influences (Richards 2004).

3.7.4 Maneuver thinking

In military affairs, it was found that a culture of maneuver thinking resulted in the most effective and efficient strategy (Richards 2004, Smedberg 1994). It was the military answer to the uncertainty and lack of trustworthy information in military operations of war.

To give an understanding and "feel" for the attitude of maneuver thinking, the following description of one of the basic principles of maneuver warfare, *Auftragstaktik*[22], is given (Claesson 2001):

> *Auftragstaktik* found its definite form between the world wars. It is based on the following fairly simple hypothesis:
>
> - As no plan, and thus no orders, remain valid after contact with the enemy, and
>
> - as the very nature of combat is confusion and uncertainty, one must
>
> - develop a system of command that allows rapid changing of plans at every level to seize the fleeting opportunities that combat confusion offers, which thus means that:
>
> + command initiative must be devolved to the lowest tactical levels, and
>
> + no formal orders can be given other than by commanders who are in physical contact with troops at the point of contact[23]; while, at the same time,
>
> + all commanders, down to section level, must react to developing combat situations in accordance with the tactical and operational INTENT, as opposed to precise orders, expressed by higher commanders two links up the chain-of-command so that
>
> + all are functioning, one might say, in harmony. And, finally,

---

[22] "Auftragstaktik" as a term and method was first developed in the German army in the 1800s (Larsson and Kallenberg 2003).

[23] Or as Sun Tzu wrote ca 490BC: "… in the field a commander need not always follow orders from the court …" (Tzu 1991).

> + this "harmony" is dependent on a common mobile military culture, or philosophy, that is enshrined in the army's doctrine and ingrained in the minds of all soldiers through a system of war maneuvers, Kriegspiele – staffrides and promotion values rigorously applied by the General Staff.
>
> This special method for planning and giving orders allows for large freedom as to the realization of orders. For instance were subordinate commanders invited to seize initiative and develop measures to be used if a tactical opportunity should arise.
>
> Such opportunities can be utilized directly without order from higher command. It was assumed that by encouraging initiatives from subordinates one would gain a greater flexibility.

Auftragstaktik relies on and thrives in a culture of initiatives at all levels, self-organization, tolerance of failure, intuitive communication, and almost thinking in one another's brains. It relies on empowering professionals at the lowest possible levels, which is the most effective guarantor for excellence (Kolenda 2003).

By making good use of the ideas and philosophy behind *Auftragstaktik* in product development, it seems plausible that *speed and flexibility will increase*, which will *yield higher quality and higher performance products.*

For this tactic to work everyone must know the overall goal and have an ability to change between different kinds of work and adapt to changing circumstance. The ability to achieve "fast transients" is a core capability according to Boyd (Richards 2004).

The advantages and efficiency of maneuver thinking has been reported in the PD literature. Wesensten et al (2005) point out that abilities that facilitate *Auftragstaktik* are situational awareness, adaptability, mental agility, judgment, initiative, anticipation, planning, course-of-action determination.

Other basic concepts of maneuver thinking are (Richards 2004):

1. *Einheit:* Mutual trust and cohesion based on shared experience and shared mental models are the basis for leading by mission statements and commanders intent. In NPD literature, we find that interpersonal trust is important for new product success (Akgün et al 2005) and for business success in general (Englehardt and Simmons 2002, Pech 2001).
2. *Fingerspitzengefühl:* Intuitive skills based on extensive experience and deep knowledge[24] that make spontaneous improvisation possible.
3. *Schwerpunkt:* The effective focus[25] of our activities that all subordinate units shall support. It is important to be able to quickly shift focus.

---

[24] Compare with the importance of personal skill and aptitude found in section 3.6

[25] This appears to be similar to "leading by a vision" in DPD, section 2.4.1

There are examples of spectacular success in new product development that seem to be a result of team design (brilliant individuals) and what could be called a maneuver culture (Sawy and Majchrzak 2004, Markus et al 2002). There is an emphasis on speed, the importance of time, or tempo in maneuver thinking that was brought into strategy theory by Musashi in 1643 (Musashi 2001) and which has been found in NPD to cause development personnel to make more careful decisions, and to more effectively implement new technologies and techniques (Swink 2003).

As a result of initiatives at all levels there naturally emerges, from a culture of maneuver thinking, a strategy of multiple thrust, which is in harmony with newer theories of business strategy that stress the importance of keeping a portfolio of options in progress (Englehardt and Simmons 2002).

Pech and Durden (2004) compare maneuver with attrition as bases for a business strategy and advance maneuver thinking as preferred strategic approach. In Pech and Slade (2003), there is an emphasis on action through maneuver, speed, and external focus. They distinguish between decision models R and P, figure 3.4.

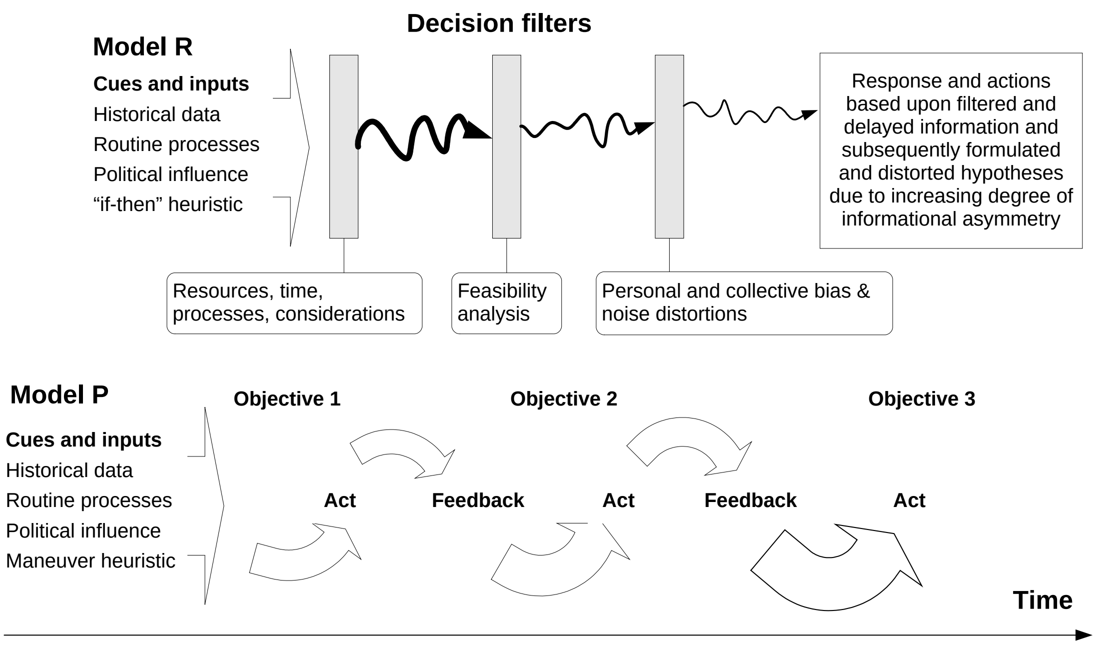

Figure 3.4. A comparison between models R (reactive) and P (proactive) (Pech and Slade 2003)

R stands for reactive and relies on tradition, historical analyses, and the "luxury" of careful planning and lengthy response and reaction times in order to attempt to shape the firms future. This is serial information processing and predicable decision making based on "if - then" calculus (Pech and Slade 2003). In such an environment, management may appear to have isolated themselves behind layers of non-porous decision filters. However, no amount of advice will help an organization to improve itself if such improvement methods expose or attack senior decision makers' greed, ignorance, or foolishness (Pech and Durden 2004).

P stands for the preferred proactive maneuver model that relies on speed and the development and attainment of rolling objectives in order to influence and shape the future. Model P describes parallel information processing as new objectives and downstream responses to actions are processed simultaneously and in parallel rather than in a serial manner (Pech and Slade 2003).

The P-model is strikingly similar to action in the knowable and the complex quadrants of the Cynefin model (figure 3.1), which is not based on maneuver thinking, but complexity theory.

Based on maneuver thinking Pech (2001) describes characteristics of an innovative organization, table 3.3, which is profitable for PD and used in DPD.

Element	**Characteristics**
Organization structure	Small semi-autonomous units.
Employees	Well-educated and highly trained.
Culture	Open culture espousing loyalty, trust, helpfulness, an action and performance-orientation, team oriented but supportive of creative and independent thinkers, encouraging of on-going learning. An atmosphere of copetition - co-operation and competition.
Management	Supportive, guiding, facilitative, high standards, high achievement, participative and tolerant of failure.
Leadership	Dynamic, motivational, communicative, influencing.
Promotion	Based on performance and ability.
Remuneration	Innovative and based on group and individual performance.
Focus	Innovation, markets and customers, external environment.
Rules and policies	Minimal and flexible for the long-term health and prosperity of the organization.
Strategies	Flexible and two pronged. Focus on growth and market dominance by providing customer satisfaction through quality and innovation, and second, outmaneuvering the competition by getting inside their decision cycle, identifying and isolating their weaknesses, and innovating at a pace beyond the coping capacity of the competition.
Tactics	Numerous, creative, unique, unexpected, a mix of both spontaneous and well planned.
Decision making	Decentralized, well conceived. Uses competitive intelligence gathering and analysis to aid decision-making.
Learning	Continual, encouraging discovery and exploration, and on-going learning

Table 3.3. A pathway to a more innovative organization based on maneuver thinking (Pech 2001)

A command and control approach often creates a dangerous illusion of direct cause and effect (Maguire 1999). Ordering people about is not in line with either findings from complexity-based organizational science or maneuver thinking. Instead ''complex leadership'' involves creating the conditions that enable productive, but largely unspecified, future states. Leaders cannot control the future because in complex systems such as organizations, unpredictable (and sometimes unexplainable) internal dynamics will determine future conditions. Rather, complex leaders need to influence networks (Marion and Uhl-Bien 2001).

Leadership thus becomes a question of inspiring, guiding, and supporting committed subordinates and encouraging them to perform freely within set limits (US Marine Corps Doctrinal Publication 6, p83).

3.8. Design the team

In a successful team, each team member's judgment is utilized, thereby realizing the inherent full capacity of the team. Further, the team is a more capable performing unit when the work is finished than it was when the work began. In other words, the team is learning. There are five simple requisites that must be in place for a team to be successful (Hackman 2002):

- A real team
- Compelling direction
- Enabling structure
- Supportive context
- Expert coaching

A real team has four features: team task, clear boundaries, clearly specified authority to manage their own work processes, and relative membership stability over some time. All of these conditions are normally fulfilled in a PD project team.

Team composition has proven to be of extreme importance. How one designs the team, is said to affect team performance 40 times more than team coaching (Hackman 2002, p208). There is a risk of achieving too little cohesion in a group of disparate talents, and if there are personality differences, communication within the team is hampered (Sample 2004). However, in a homogeneous team there is less learning and creativity. For the specialization, typical of a good team, it is advantages to recruit team members that complement each other's competence. The combined competence is larger for such a group, figure 2.5. A heterogeneous group performs better than a homogeneous (Pech 2001).

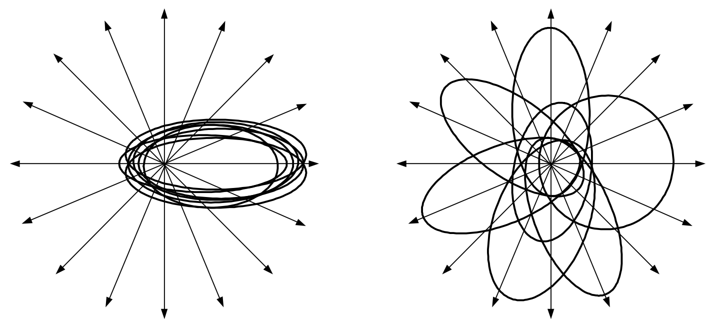

Figure 3.5. The competence of a team of disparate talents is larger than that of a team of look-a-likes (Pech 2001).

The compelling direction should ideally deepen the meaning or elevate team members purpose in life and it should be challenging to be interesting. Such a compelling direction energizes the team. A clear direction helps orient the team and align efforts. With possibly positive consequences of the work follows engagement that foster full utilization of knowledge and skill (Hackman 2002).

An enabling structure starts with a sound project organization, with clear statements of responsibilities, code of conduct, and division of work. The team should preferably not consist of more than a handful of team members as motivation and engagement usually is larger in small teams. A well functioning and supportive infrastructure including locations, communication equipment, computers, software, etc are all a part of an enabling structure (Hackman 2002).

Supportive context in this case means open borders, a free flow of information, and a forgiving atmosphere where mistakes are allowed if they are the result of meaningful risk taking. There should be some kind of reward system (Hackman 2002).

Expert coaching must take into account the three aspects of group interaction, namely the amount of *effort* members apply to their collective work, the appropriateness to the task and situation of the *performance strategies* they employ in carrying out their work, and the level of *knowledge and skill* they apply to the work (Hackman 2002).

Team leader intervention mostly has either of two purposes (Hackman 2002): to minimize process losses, or to increase process gains. Intervention that addresses effort is *motivational* in character; its functions are to minimize free riding and to build shared commitment to the group and its work. Intervention that addresses performance strategy is *consultative* and intends to minimize thoughtless reliance on habitual routines and to install inventive ways of action that are aligned with task and situational requirements and opportunities. Lastly, intervention that addresses knowledge and skill is *educational* in character.

3.8.1 Group problems

The shadow system has already been discussed[26] where it was pointed out that informal structures (the shadow system) self-organize and emerge and persist in a way that is remarkably robust to changes in the formal organizational structure (Anderson 1999). Further, the shadow system is very much intertwined with, yet constantly attempts to undermine, the legitimate hierarchy (Kurtz and Snowden 2003).

It has also been discussed[27] how an organization at least partially is a product of human intention (Rowland 2004), and that an organization besides having outspoken predetermined goals, may harbor unconscious intentions (Buckle 2003), residing in the shadow system. Interaction between the shadow system and the individual may be "kept in the dark" and therefore invisible to management (Lindholm 1998), or in other words: "it is when you turn on the light that the shadows become visible[28]" (Hall 2005).

Many of the intentions driving organizational behavior are publicly understood and sanctioned, this is "theory espoused". However, some purposive behavior in organizations remains unconscious and is present in "theory in use". These may detract resources from managerial objectives and obstruct organizational efforts regardless of the desires of any one manger. The more so, the less they coincide with sanctioned intentions.

Furthermore, the organization creates the team of instrumental reasons; there are motives (conscious or unconscious, outspoken or clandestine) behind the creation of the team, while the individual participates in order to satisfy personal needs (money, social recognition, etc), which may or may not be congruent with the organization's goals (Lindholm 1998).

To complicate this further, there are the aspects from the difference matrix[29], which is unique for every difference factor that affects the organization, such as power, money, place, topic, personal style, and language (Eoyang 2004).

As can be seen, conditions for product development in any organization are thus truly very intricate and complex.

3.9. Conclusions

[26] Section 3.4 Organizations as complex systems, section 3.5 Order and un-order
[27] Section 3.4 Organizations as complex systems
[28] This was how the words fell when the author was told that the Swedish head office had discovered that most employees at their factory in China were relatives of the local manager.
[29] Section 3.4.2 Self-organization and emergence

Often in PD literature methods are described/prescribed without much regard for the characteristics of the situation at hand, or those that make up the system, and who are expected to use the methods. However, this chapter shows how important it is to appreciate the complexity of the situation at hand. Further, there is a progression from abstract and generic to concrete and special that looks like this (Richards 2004):

Culture ➔ Strategy ➔ Plans (tactics) ➔ Work (techniques are applied)

Culture determines what strategies are possible or acceptable. Then plans are born out of accepted strategy. Plans are transformed into work. It follows that our culture, our outlook, our view of the world is important for the way we perform product development. The more so when we understand that our paradigm and its invisibility, in force of it being a paradigm, is the hardest prejudice to fight and therefore potentially the most dangerous.

If we believe in a linear, ordered world where simple causation exists, then planning is indeed possible, and machinelike action will yield desired results. The human mind seems to favor this worldview and humans appear to be born with an intuitional idea of simple causation (Pinker 2002). Maybe it is comforting to think of the world as ordered and, perhaps, purposive.

Scientific findings in the last decades, however, have given us a new understanding and appreciation of the world as a complex system. This has several ramifications, as presented earlier in this chapter:

- It can be difficult to associate effect with cause, making prediction virtually impossible.
- System history plays an important role in defining the state of the system as well as affecting system evolution. Future development is dependent on how we came to be here.
- It was for a long time assumed that systems could be controlled, when in fact they can only be influenced.
- Self-organization leads to emergent properties and efficiencies unattainable with top-down direction.
- The system has within itself a model of its environment and its purpose; it is teleological.
- Informal structures self-organize, emerge, and persist in a way that is remarkably robust to changes in the formal organization.
- Understanding requires multiple perspectives on the nature of the system. Narrative techniques are particularly powerful.

- Perfect information will not remove uncertainty.

Methods created based on an assumption of an ordered, linear world, are probably unsuitable for situations where circumstances are complex. For example, with a linear world conception, when a plan fails to come together, it is seen as a flaw in the plan, not as a natural consequence of how the world is constituted, which would be the natural inference based on a complexity worldview.

The complexity shown by modern science to be ubiquitous is of course not new, it has always been there and especially so in uncertain undertakings involving many humans, as in warfare and increasingly in business. It is not surprising then that from such different fields as military affaires, business strategy, and complexity theory, a common view has emerged that the preferred strategy for handling complexity is learning, not planning.

For successful action, it has been found that uncertainty and changing circumstance, so typical of product development, is best handled by utilizing human judgment through agile adaptation to shifting circumstance, relying on self-organization and emergence, making use of the latest gained knowledge. Even act in order to learn, when an understanding of the problem develops concurrently with the solution.

The dynamic methods, such as DPD, seem to best correspond to this new understanding of the world as a complex system, while the need based, static methods (SE/CE, IPD, Stage-Gate™, etc) appear to have been designed for an ordered, stable world, that frankly does not exist.

4. Research on product development

The reason for researching product development projects should be to improve on product development theory, so that the scientific community, as well as practitioners, who use the new improved theories, their organizations, and the users of the new products can profit.

Or as Reynolds (2004) puts it: "[Our research]…ought not to be about unveiling some absolute truth regarding some objective social reality, but a process of inquiry to improve our systems design". The method for doing so, in this thesis, is insider action research (IAR), which belongs to the qualitative methods.

Since qualitative methods occasionally are debated for allegedly failing to be "objective", this aspect is discussed in this chapter, as well as views of "good" research and additional aspects of researching complex systems.

4.1. The question of "objectivity"

The question of objectivity is brought up here because qualitative methods often come under fire for allegedly being subjective, which is regarded as bad, compared to quantitative methods that are perceived to be objective.

4.1.1 Subjectivity in a product development team

Team members all have their own subjective view or mental representation (that is a result of position in a hierarchy, previous experience, knowledge, etc, (Hummel 1991)) of the situation at hand. This is exactly what a manager has to deal with in a product development team. That is why a manager may ask himself, "What's happening here?" (Jönsson 2004).

These subjective views are all there is to work with. There is no completely "objective" description available and can never be. There are only subjective experiences, where each person "owns" a unique perspective on the situation (Hutchins 1991). However, this subjectivity is important, for it is the agent governing actions and therefore worthy of scientific study. For not only does subjectivity represent a legitimate focus of research but also a legitimate component of research methodology enabling researchers to enter, experience, and share the perceived worlds of the subjects (Ford 2004).

As a project manager/leader, one presents a subjective description of the situation at hand that is so shaped that it connects to the subjectivity of each team member. Because that is the only way, that one can be sure of full-hearted cooperation from each team member. In this intersubjectivity, if all agree to respect each other's definition of the problem, a puzzling out of a synthesis that leads to a solution is possible (Hummel 1991). The action here of the manager is the opposite to that of many analytical scientists who through analysis take reality apart, while the manager through synthesis put reality[30] together (Hummel 1991).

4.1.2 Objectivity

It is common to make a distinction between the world outside of the mind, the real world, existing independent of the mind on the one hand, and on the other the world inside of the mind, a reality dependant of the mind for its existence. The world outside of the mind, the real world, is perceived by the mind through the body that is a necessity for the mind to exist (Atkins 2002, Pinker 2002). This has lead to much debate and labor among philosophers.

Most scientists today agree with Cartesian-Newtonian metaphysics that says that: "[…] there exists an external world, whose properties are independent of any individual human being and indeed of humanity as a whole; ... these properties are encoded in "eternal" physical laws; and ... human beings can obtain reliable, albeit imperfect and tentative, knowledge of these laws by hewing to the "objective" procedures and epistemological strictures prescribed by the (so-called) scientific method" (Lovejoy 2000).

Even if we cannot know for sure (we do not have "God's eye view") what the *real* world is *really* like, and how well our mental representations correspond to that world, it nevertheless seems reasonable that evolution has at least forced homo sapiens to develop an *efficient* mental representation of the external world (Pinker 2002, p 214), leading to a utilitarian perspective, seeing the standard of objectivity as *successful action in the world*, making objectivity inseparable from interest, and ideals of disinterest and detachment, meaningless (Chalmers 1990). Science is a way to create utilitarian value. Higher values, including the pursuit of truth for its own sake are irrelevant since the methodological and epistemological standards for science "are subject to change in the light of practical achievements". There is also the collective achievement of the scientific community that through peer review and other means (scientists jealously checking each other, etc) has a process of neutralizing individual bias and securing a form of objectivity (Bauerlein 2001). Continued testing will eventually overturn theories that misrepresent the natural world "as it is" (Ritchie 1994).

It is also likely that language functions effectively to connect to that external reality, since by everyday experience we find that language is functional for communication between human individuals. Or in the words of Keith and Cherwitz (1989): "…since it is clearly the case that the vast majority of the time we understand each

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[30] The subjective reality perceived by team members.

other well enough to get along there must be something objective about language that permits it to be a medium of exchange”.

4.1.3 Positivism

For the later decades of the 20th century, there has been a fierce debate between chiefly two schools of thought as regards objectivity, the Positivists and to some extent the Empiricists on one side and on the other side the Constructionists, also called Relativists that were later followed by the Postmodernists.

The Positivists cling to a strong statement of objectivity: scientific knowledge is the only reliable knowledge. It is reliable because it is objective. It derives its objectivity from the objectivity of observation made by a detached observer. The way in which empirical scientists look at the world is sometimes described as "scientific attitude." In order to be objective observers, scientists must be indifferent, disinterested, neutral and impartial. Personal opinions or preferences have to be suspended. No subjective elements are allowed to intrude. Science is believed to be reliable if it is based on objective and verifiable observational statements, which can be transmitted into laws and theories (Korab-Karpowicz 2002).

One of the strongest proponents of objectivity in science was philosopher Karl Popper who argued a thesis involving the existence of two different senses of knowledge or of thought:

1. Knowledge or thought in the subjective sense, consisting of a state of mind or of consciousness or a disposition to behave or to act, and
2. Knowledge or thought in an objective sense, consisting of problems, theories, and arguments as such (Korab-Karpowicz 2002).

However, here Popper forgets that: “Science has no way of transmuting the contextual knowing of many individuals into the objective knowledge of a knowerless abstraction”, there is no generic knower, only concrete people who would see and judge things otherwise if their experiences had been otherwise (Caneva 1998).

Popper radically distinguishes "objective" theories, problems, and arguments, from "subjective" states of mind. However, just as scientific knowledge, derived from observation, presupposes the scientific attitude of being a detached, objective observer, so also its verification and sharing with other members of the scientific community requires the same attitude. Without this attitude, science would be neither objective nor inter-subjective. Objectivity and the scientific attitude are thus interrelated. If this is the case, subjectivity must indeed be taken into account, and objective knowledge is not independent of the human mind as is commonly believed. It is dependent upon the states of mind, which constitute scientific attitude: on being indifferent, disinterested, neutral, and impartial (Korab-Karpowicz 2002).

To this can be added that the realist Popper when arguing non-subjective knowledge borders to mysticism. The objective reality, according to Popper, was not a reality that human beings could understand, a stance that led to his being described as an "irrational rationalist" (Lovejoy 2000).

A further problem with the strong positivist view is that mental objects such as thoughts, feelings, or sensations are considered private and beyond the scrutiny of science. So only observational statements about physical objects can be verifiable and produce knowledge (Korab-Karpowicz 2002), leaving sociology, organizations, product development, psychology, decision-making, etc, outside of scientific study.

4.1.4 Constructivism

The positivist objectivity was challenged by the Constructivists who "… tend to share a common relativism about knowledge and truth, which they reduce to collective belief, disciplinary and community agreement and conventions of language. Taking objectivity to postulate an impossible value-free, neutral, or aperspectival position in the process of knowing, they see it as a product of the illusion that scientific knowledge is not a human and social construction, but something simply discovered and true" (Zagorin 2001). One problem with relativism is that it easily leads to an anything-goes-attitude, thereby overlooking the extent to which theory is dependant on nature.

The Constructivist/Relativist position has been criticized by among others Hunt (1993), who summarized the main constructivist arguments against objectivity, table 4.1, and then refuted them one by one.

	Arguments Against Objectivity	Philosophy and History of Science Sources
1	Objectivity is impossible because the language of a culture determines the reality that members of that culture see.	Sapir (1949), Whorf (1956)
2	Objectivity is impossible because the paradigms that researchers hold are incommensurable.	Kuhn (1962), Feyerabend (1975)
3	Objectivity is impossible because theories are undermined by facts.	Kuhn (1962), Feyerabend (1975) Goodman (1973)
4	Objectivity is impossible because the psychology of perception informs us that a theory-free observation language is impossible.	Hanson (1958), Kuhn (1962) Feyerabend (1975), Goodman (1973) Churchland (1988)
5	Objectivity is impossible because all epistemically significant observations are theory-laden.	Kuhn (1962), Feyerabend (1975) Brown (1977)

Table 4.1. The constructionists' arguments against objectivity in science according to Hunt (1993)

Hunt (1993) holds that scientific knowledge, in which theories (groups of statements), laws, and explanations are primal, must be *objective* in the sense that its truth content must be *intersubjectively certifiable*. Requiring that they be empirically testable ensures that they will be intersubjectively certifiable since different (but reasonably competent) investigators with differing attitudes, opinions, and beliefs will be able to make observations and conduct experiments to ascertain their truth content. And also: "In science all knowledge claims are tentative, subject to revision on the basis of new evidence. The concept "certainty" belongs to theology, not science" (Hunt 1983).

The minimum norm, therefore, for a community's knowledge claims to be relied on, is for the community to reject reality relativism and constructionism. Because such doctrines specifically state that their knowledge claims do not "touch base" with any reality other than that "constructed" by the researchers themselves (Hunt 1993).

4.1.5 A synthesis

In search of a viable position, Hanna (2004) "…believes that the proper account of science lies in a synthesis of positivist and anti-positivist views". The attitude is utilitarian: "Roughly speaking, the proposed ideal of scientific objectivity is *effectiveness* in the informal but technical sense of an *effective method"*. The everyday realism gives substance and force to the scientific realists' conception of objective reality.

The philosopher Paul Ricoeur argues for a dialectical middle way that undercuts the dualism of subjectivity and objectivity by showing their mutual implication and logical dependence (Atkins 2002). Ricoeur points to the coupled duality of explanation and understanding. *Explanation* refers to the process typical of the natural sciences, of constructing causal relations between data through the use of signs, codes, and logical system. *Understanding* refers to a subject's experience of meaning. Something that is understood is something that is amenable to explanation, while all explanations draw from a background of an understood situation.

Now that multiple perspectives and paradigms have been accepted and many contemporary theorists move freely from one perspective to the other, Meckler and Baillie (2003) propose a "middle way" between the postmodern rejection of notions of truth and objectivity on the one hand, and on the other the overrestrictive and metaphysically inflated version of these concepts that they call Objective Truth. Their arguments are based on recent philosophical writings, by Searle (1995), Goldman (1999), and Hacking (1999). By skillful application of arguments, their article provides a theoretical base for the emergent "middle way" view. However, even the shortest possible description of their arguments covers several pages so therefore only a simple sketch of their main point is given.

Following Searle, Meckler and Baillie (2003) argue that *subjectivity versus objectivity is an oversimplification*. One has to consider the epistemic and the ontological senses of these two terms.

1. A statement is *epistemically objective* if its truth (or falsity) is independent of any desires, preference, or other personal attitudes relating to the speaker's point of

view. A statement is *epistemically subjective* if its truth essentially depends on these factors.

2. The ontological sense of subjective and objective applies not to statements or judgments but to objects and properties in the world. Something is *ontologically objective* when its existence does not consist in or depend on anyone perceiving it or thinking about it.

To call some aspect of the world ontologically objective is to say that it would still exist in the total absence of minds. By contrast, to be ontologically subjective is for its existence to depend on minds[31].

Natural science aims at both epistemic and ontological objectivity (table 4.2). Beliefs and desires are all irrelevant to the truth of statements about it. Social science is more complicated. Although it can achieve epistemically objective judgments, the domain itself is ontologically subjective, being partly constituted by collective attitudes.

Epistemic	**Ontological**	**Example**
Objectivity	Objectivity	Natural science
Objectivity	Subjectivity	Social science
Subjectivity	Objectivity	Pseudoscience, fiction, art, etc
Subjectivity	Subjectivity	Delusions, pseudoscience, fiction, art, etc

Table 4.2. Four possible combinations of statement characterization (Meckler and Baillie 2003)

Meckler and Baillie (2003) show that *the claims of organizational science can be true in the sense of expressing epistemically objective facts* while acknowledging that the realm of organizational science as a whole is ontologically subjective. However, it does not follow that they are precluded from speaking truly about these matters.

Both the strong positivist and the constructivist/relativist position lead to mysticism or inconsistencies and contradictions. There is a middle way, gaining more and more support, where objectivity is given an efficiency aspect (Chalmers 1990, Hanna 2004), and where everyday language is seen as sufficiently connected to reality (Atkins 2002) to be used for making verifiable judgments about the world.

Sciences involving the study of human actors may be ontologically subjective but can still be epistemologically objective (Meckler and Baillie 2003). This seems to pave the way for qualitative research, such as case studies. This is important if we want research to be of value to practitioners since "the major alternate means of acquiring

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[31] Incidentally, this is exactly the distinction made by scholastics in the 16th century, who differentiated between *conceptus objectivus* and *conceptus formalis*, where the later corresponds to *subjective concept* or being totally in the mind (Green 2005).

knowledge that managers use is story-telling, in written form: the case study and descriptive narratives" (Hummel 1991).

Qualitative research relies on induction, which is strongly endorsed by philosopher Harold Jeffrey (Galavotti 2003). That qualitative research is in harmony with the "middle-way" view of objectivity is assured by Avis (1998), who maintains that, "empirical science provides an epistemology and methodology that can accommodate the practice of qualitative research and that we do not need an alternative paradigm to underwrite qualitative methods".

4.2. Action research

Action research (AR) has been used in Western civilization since Aristotle's days and has in the last century foremost had an emancipatory inclination (Boog 2003), as its early advocates in the last century worked with empowering low status or suppressed social groups. This implied a design inclination to their action research.

Most action research is still geared towards change, emancipation and improving a group's function where typically an organization is "healed" (Meehan and Coghlan 2004). Action research has also been used for developing a strategy (Roos et al 2004), monitoring continuous quality improvement (Prybutok and Ramasesh 2005), facilitate stakeholder participation in planning (Tippett 2004), for researching appropriate strategy for design theory building (Markus et al 2002), learning in product development teams (Purser et al 1992), for modeling the way risk management is handled in product development (Gidel et al 2005), and even how to manage personal knowledge (Zuber-Skeritt 2005), to name but a few.

Action research generally is based on the non-positivist belief that knowledge in the social sciences must improve practice, be of utilitarian value, in order to be valid and useful. Integrating theory and practice, as well as explicit and tacit knowledge[32], theory/learning can be created through experiential knowledge by following a continuous process of (Kolb 1976, 1984, Boyatzis and Kolb 1995, Zuber-Skerritt 2005):

- Having a concrete experience
- Observing and reflecting on this experience
- Forming general principles and concepts, and

Testing these concepts in actual practice and gaining new concrete experience, and so forth

A search of action research literature indicates that almost all action research has been on organizations of a permanent nature. These can be likened to machines

[32] We know more than we can tell; the part we can tell is explicit, the rest is tacit knowledge.

processing input and delivering output in a steady fashion governed by rules and regulations. The persons in the researched organizations act out their prescribed roles much like a machine part fulfill its function. The cyclic iterative nature (plan, act, observe, reflect) of most action research (Zuber-Skeritt 2005) is intended to improve on the organization just as if we were fine-tuning a machine.

4.2.1 Insider Action Research, IAR

In action research, the researcher can be an outsider (not formally belonging to the studied group) or an insider. As an insider, the researcher can be an observer, team member, or a team leader (Björk 2003). An additional position would be e.g. sponsor. As regards time spent on different activities there are differences between the three roles, figure 4.1.

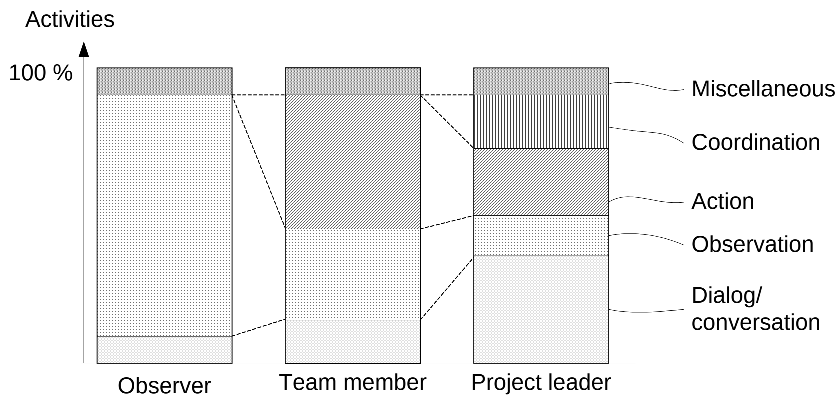

Figure 4.1. Schematic time distribution of IAR "field work" (Björk (2003)

There are also differences in dynamics between the two modes (outsider/insider) of research (Coghlan 2001), especially in terms of preunderstanding. If an insider action researcher (to Coghlan this is always a manager), the researcher is an active member of the field of interest. Moreover, if this researcher/manager is an expert in his field of practice, his knowledge and understanding of the studied subject is much deeper than that of any outsider, irrespective of that outsiders standing within the scientific community.

The insider action researcher is knowledgeable of the organization's everyday life and history, the jargon, the culture, what to talk about and what not to talk about, what occupies peoples minds, the informal organization, who to turn to for information, and which objectives are important and which are just empty talk.

When insiders make inquiries, they can do so using the internal vocabulary of the organization and without rising suspicion about their presence. They can follow up on answers and obtain richer data than can an outsider researcher. The insider researcher can participate in discussions or merely observe what is going on without others necessarily being aware of his presence. In this way insider action research can be said to have a larger potential for authentic observation than outsider action research since in the former case the observer disturbs the observed object much less, which is opposite to common beliefs.

When the IAR researcher is actively participating in team activities, either as a team member or as a team leader/project leader (PL), then this is called participation action research (PAR), figure 4.2.

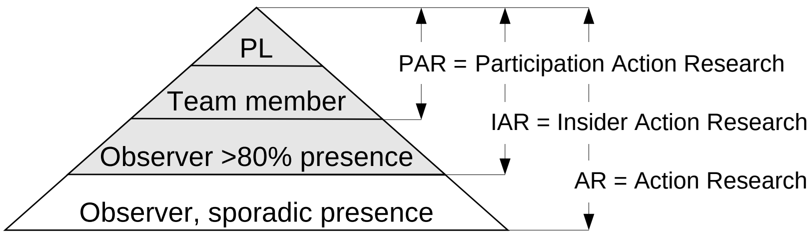

Figure 4.2. (Same as figure 1.1) Research mode depends on time spent in the system (modified from Björk 2003). PL = Project Leader

A favorable situation for performing insider action research, IAR, is set up when the researcher is inside an "object" acting as a manager/entrepreneur/team member or observer at the same time as he has access to a scientific environment. To compare findings, the researcher also has to conduct complementary classical research, as it is not possible to do action research inside for example a competing company (Ottosson 2003), figure 4.3.

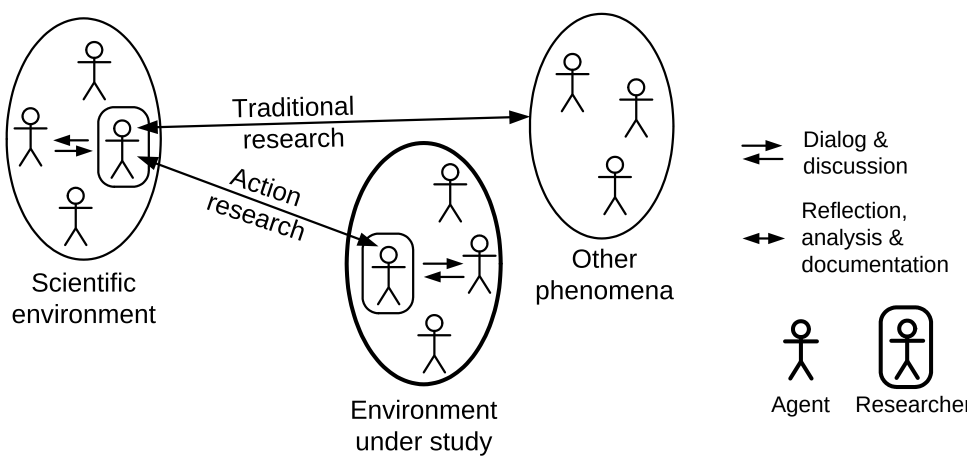

Figure 4.3. Supplementing AR with traditional research yields an optimal research situation (Ottosson 2003)

A further advantage is the quality or reliability of data gathering in IAR (Ottosson 2003), figure 4.4. As the researcher is present where things happen, even the smallest bits and pieces do not automatically go unnoticed, as is so easily the case in quantitative research (Lewis 2001).

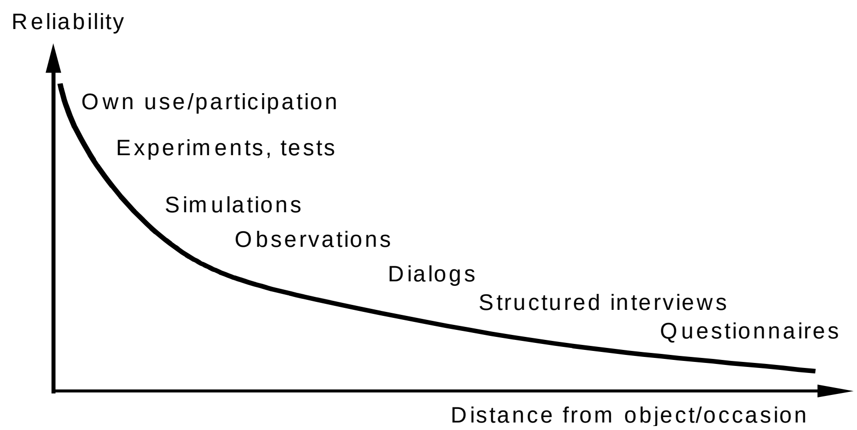

Figure 4.4. Reliability of information vs. distance from object (Ottosson 1999B)

There are also disadvantages to insider research compared to outsider research. These are the risks of being too close to data, not seeing things with fresh eyes and the risk of assuming too much when interviewing, and as a result not probe deep enough. The researcher may think he knows the answer and does not expose his thinking to alternative reframing. This can be countered by having the insider researcher periodically visit an external scientific environment for consultations (Björk 1999), figure 4.3.

The insider researcher may find it difficult to obtain relevant data, because as a member he has to traverse departmental, functional or hierarchical boundaries, or because as an insider, he may be denied deeper access, which might not be denied an outsider.

These factors pose considerable challenges to the researcher and require rigorous introspection and reflection on experience. The most important issue to handle for the insider researcher is organizational politics, and therefore the researcher needs to be politically astute and somewhat of a "political entrepreneur" (Coghlan 2001).

Coghlan (2003) further divides action research into mechanistic and organistic. By organistic is meant action research projects in which the inquiry process is a value in itself, while mechanistic action research encompasses traditional action research leading to pragmatic outcomes such as the management of change.

4.3. Action research on product development

Product development projects are not permanent, but temporary, dynamic, complex, and unique systems that do not just transform input to output but create output through a design process, thereby relying on people's fantasy, judgment, skill, and foresight. The wanted result of product development is requisite conditions for the production and sales of at least one new product. Therefore, action research on such systems will lack the typical cyclic process. Instead, findings from one project will be carried into the next project and used if appropriate to improve on that project.

4.3.1 The special nature of PD from a research standpoint

As product development projects and especially new product development projects are complex systems (e.g. Jönsson 2004, Vajna et al 2005, Björk and Ottosson 2006), aspects of time are very important in several ways.

1. Time as such is irreversible yielding a chain of causality that cannot be reversed; a developed product cannot be undeveloped, a learned skill can hardly be unlearned, etc.
2. Tempo is important. By which is meant the pace with which decisions are taken and actions are performed. Tempo is important since the development project is an open system that must adjust to outer circumstance.
3. In complex systems, history is important since the system and its environment is formed by its history. History is ever present as trigger points for often completely unsuspected events (Buchanan 2001, Cohen 1999, McKelvey 2004, Richardson 2005).

These points in themselves make any product development project unique. There is also sameness between projects; otherwise, it would be fruitless to study them with the aim of making useful observations, from which to infer theory.

Point 1 above has as effect the impossibility to carry out controlled experiments in the classical sense or to repeat experiments in that same sense. The possibility to ”replicate experiments” is not completely lost though, as there is always the possibility to find and study several similar cases.

A further consequence of product development projects being complex systems active among other such systems is that unpredictable and completely unplanned events may occur. There can be new legislation, new knowledge (new scientific understanding or new technology), new customer preferences, and competitors that completely change the picture, to name but a few.

As described in chapter 3, in a complex system small causes can have large effects. The problem is that there is no way of knowing beforehand, which effects are important, and since complex systems have their own highest computational capacity (Langton 1990) it is impossible to simulate such systems in a meaningful way (there might even be computational irreducibility (Wolfram 2002, p1132)), making e.g. detailed long-term planning meaningless. In order to monitor such systems, the observer must therefore be almost continuously present in the system (Ottosson and Björk 2004).

It should be understood that commercial product development projects are human activities of a very special character, often staffed and managed by people who may have a considerable amount of experience. An expert33 project manager most certainly will perceive situations and act differently from a novice (Klein 1999 and 2003), and will often have a good understanding of the history of the project milieu and how that affects the project. Therefore, much of what happens might go completely undetected by the non-participant researcher.

4.3.2 Reported benefits from using IAR on PD

There are several benefits from using insider action research, IAR, when researching PD projects, reported in the literature. The researcher is continuously present in the system (Björk 2003), and is knowledgeable about the system and its history (Björk 2003). Further, from Ottosson and Björk (2004):

- IAR yields a minimum risk of losing valuable information/data due to forgetfulness or incorrect reconstruction. When reconstructing past events, there are risks of misunderstandings. The researcher has no opportunity to consider the circumstances outside or inside the studied process that may have influenced the result.
- Firsthand information eliminates the influence of other people's understanding of the situation and their ways of expressing it.
- Opportunities exist to rapidly correct interview manuals or to clarify misunderstandings between the questioners and the respondents.

The very best position in order to get the most out of IAR on PD is to be project manager and researcher. There are three major advantages being a manager and researcher compared to being team member/researcher (Ottosson and Björk 2004).

- The experience and knowledge gained from participating in the studied process provides the researcher with the unique opportunity to lead a later implementation of the research findings. The organization feels familiar and confident with the ongoing process and the person leading it.
- The result can be useful for practitioners; this is often lacking in current research findings when classical research methodology is used.
- The user satisfaction of the products can increase when a holistic view is accepted as a mediating tool in research and in product development practice.

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[33] It requires four hours of training per day, six-seven days a week for ten years to become an expert (Klein 1999, p302).

Another factor is unspoken information that is extremely difficult to take into consideration when using classical research methods, but is captured in a natural way when using IAR (Ottosson 2003).

4.4. Safeguarding good scientific research

> The value in action research is not whether the project was successful or not, but rather that the exploration of the data, i.e. how a particular project was managed, provides useful and interesting theory which may contribute to learning on the subject of project-based management (Coghlan 2001).

Good scientific research that yields useful theory is built on several cornerstones. One of those is rigor, which in action research refers to how data are generated, gathered, explored and evaluated and how events are questioned and interpreted through multiple action research cycles (Eden and Huxham 1996).

Action research project managers/researchers need to show (Coghlan 2001):

1. How they engaged in action research cycles (diagnosing, planning, taking action and evaluating), and how these were recorded to reflect that they are a true representation of what was studied.
2. How they challenged and tested their own assumptions and interpretations of what was happening continuously through the project.
3. How they accessed different views of what was happening which probably produced both confirming and contradictory interpretations.
4. How their interpretations and diagnoses were grounded in scholarly theory, and how project outcomes were challenged, supported or disconfirmed in terms of the theories underpinning those interpretations and diagnoses.

To the above could be added how important it is for the researcher to thoroughly contemplate what theory in use the researcher subscribes to. Which is to challenge the challenge in point two above, because our analysis of the researched object is filtered through our theory in use (Jönsson 2004), which is another way of saying that our observation depend on our orientation[34].

Ottosson and Björk (2004) state that "Total *reliability* does not exist in industrial processes simply because the processes cannot be repeated with the same result. The reason for this is that product development processes are dynamic and truly complex, which is why reduction to one simple factor that is kept stable during measurement provides artificial knowledge. The measuring method also influences reliability in such a way that the longer the distance is to the studied object the lower

[34] Section 3.7.3 Aim or purpose of strategy, the OODA loop.

the reliability factor becomes. *Validity* is also problematic when studying dynamic complex systems, as the systems change continually. Thus *causality* is the best that can be achieved studying real industrial processes".

Björk (2003) gives an extensive and thorough argumentation for the requirements on insider action research as applied to research on product development projects. By first remarking that general quality requirements of scientific documentation is that knowledge is communicable, relevant and trustworthy, where trustworthiness depends on validity, controllability, credibility and reliability, Björk continuous by arguing point by point the validity, reliability, credibility and relevance of using insider action research on the development projects she studied.

4.5. Safeguarding the research of this thesis

Instead of repeating arguments so eloquently put forth by another researcher, the author will limit the discussion to the short list in the following section, which will address the four points above as well as the points put forth by Björk (2003).

4.5.1 Relevance of this thesis

Regarding action research rigor (Eden and Huxham 1996), following the order in the preceding section, the following can be stated:

- The action research presented was planned and evaluated in collaboration with the authors scientific advisors. Data from the projects (Case 1 and 2) and research was recorded in the form of notes, diaries, emails, documents, drawings, CAD models and faxes.
- Assumptions and interpretations of what was happening were continuously discussed in an ongoing dialog between the author and his tutor as well as with other people who possessed knowledge of the field and supplementary areas. Throughout the two projects, relevant literature was studied in an attempt to improve on project efficiency (these were commercial projects) and understand project dynamics.
- We can never know for sure what people think, only construct assumptions to fit with reality, as we perceive it. As project manager at a consultancy company dependant on its customers and the performance of the work done, one is constantly questioning assumptions and tries to see things from different angles. The author tested his assumptions in dialogs with others.

How interpretations and diagnoses were grounded in scholarly theory is shown in chapters seven and eight.

4.5.1.1 Validity

Validity concerns the relation between the results of the study and its research questions. Are we solving the right problem in the study? (Taxén 2003, p.32). In the qualitative tradition, validity is superior to reliability, which means that if validity is good, reliability will automatically be good (Björk 2003). It follows that the validity of the text is a matter of judgment on the part of the reader.

4.5.1.2 Reliability

"Reliability concerns the quality of the research results. Something is reliable if it is worthy of reliance and trust. Are the claims well grounded? Is it possible to follow the argumentation?" (Taxén 2003, p32).

The two product development projects studied in this thesis were Case 1: a fully commercial project performed on behalf of a customer and Case 2: a large internal development project that was scrutinized and approved by the board of the company, which is noted at the Stockholm Stock exchange. The author has used several data sources such as dialogues, notes, diaries, emails, documents, drawings, CAD models and faxes. Most of this documentation is archived at the company.

The author has written one peer reviewed conference contribution (Holmdahl et al 2005) and one article that is accepted for publication in Journal of Engineering Design (Ottosson and Holmdahl 2006).

4.5.1.3 Credibility

"Credibility may be understood as an assurance that empirical evidence exists for the results obtained and that reasonable interpretations have been made" (Svensson 1996).

As previously explained, this thesis is based on two projects. Case 1 is a fully commercial project that is easily identified as names of the companies and people involved are given. Records of the project are available in the archives of those companies and people involved can be contacted for reference. Case 2 is an example of a company internal product development project aimed at accomplishing disruptive business development by aid of a business innovation. For the purpose of commercialization, this project was amply reported in relevant journals (Brandt 2000, Bergh 1999, Lundgren 1999A, Lundgren 1999B).

The participation action research performed on Cases 1 and 2, as reported in this thesis, will, it is hoped, convince the reader that new knowledge regarding product development projects has been made available, and that the projects have been given a fair and balanced treatment.

The way we orient to what we observe depends on our cultural traditions, genetic heritage, previous experience, etc (Richards 2004). These factors can be seen as the filter through which we construct our view of reality. Therefore, a description of the authors pre-knowledge is given in Appendix 1.

4.5.1.4 Loyalty issues

There are all kinds of loyalties; socially based loyalties such as paying a social dept or keeping a friendship. We are loyal to our knowledge and worldview, perhaps because questioning them requires too much energy or excites angst (Dixon 1994). We are loyal to relatives and friends out of a sense of fidelity. We are loyal to organizations that we depend on or are somehow connected to because that will strengthen them, which will benefit us. We are loyal to our beneficiaries. There is also loyalty as an altruistic action.

Loyalty shifts over time and is dependant on circumstance, but is also dependant on personality and temperament of the researcher (Keirsey 1998). Humans differ as to how dependant they are of what others think, whether they are cooperative or utilitarian, how sensitive they are to political correctness, if they have a strong inner compass, etc.

Loyalty is brought up because it filters or colors findings and observations, what we chose to emphasize and what we tend to play down.

There is an additional factor; loyalty is time dependant and often the need for loyalty diminishes with time. This is the case with loyalty to a commercial company where for instance trade secrets lose importance over time. This is also acknowledged in the science of history where often very private information about humans that ones lived is revealed. In modern states, secrets are not forever but for a limited time.

This is a fortunate outcome of waiting several years before publishing a description of the two projects (Case 1 and Case 2) in this treatise and its findings. It is felt that time has released the author from any censoring loyalty towards the organizations and humans involved and that the benefits to humankind from taking part in the findings have precedence over any remaining loyalty.

4.6. Analysis and conclusions; in-depth view of the research process

There are several ways to perform research on product development projects. The so-called quantitative methods of sending out questionnaires and performing structured interviews of practitioners, dominates, while action research, which is a qualitative research method, is more seldom used.

Whatever the method, one reason for conducting research on product development is to improve practice, a so-called second order change.

4.6.1 Second order change

In action research on the social system that is a product development project, the emphasis is on achieving second order[35] change (Coghlan 2003), which in this case means to modify the present theory or create a new theory[36]. Our action research can thus be said to be design oriented (Romme 2004). Preferably, one would also like to accomplish third order change, shown as "triple loop action learning" in figure 4.5, but social systems are as a rule very resistant to such change (Casey and Brugha 2004).

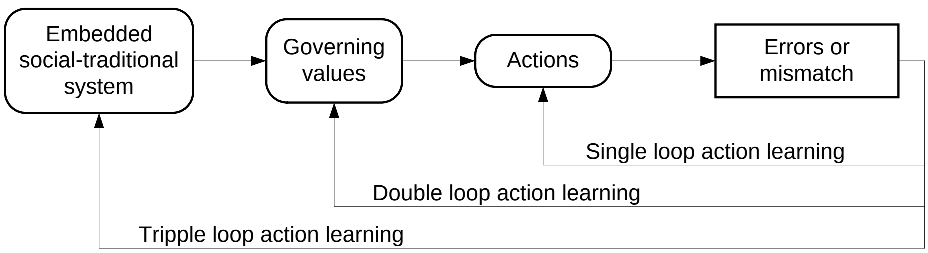

Figure 4.5. Organizational learning (Argyris and Schön 1974)

When Argyris' model is used to describe action research on product development, the loops in figure 4.5 will for the most part, due to the temporary nature of product development projects, not take place within one and the same research object. This is in contrast to the common understanding of the model where it is seen as corrections within the studied system due to research carried out on that system. Here it represents how theory is improved by being corrected and/or enlarged by findings from one project that is then used to improve upon the organization and management of subsequent projects.

A further basis for productive reflection is the discovery by Argyris of the discrepancy between *what rules people say they follow* and *what rules can be deducted from watching their actions*. This is the so-called *theory espoused* versus the *theory used* (Argyris and Schön 1974). By watching team members' actions and keeping a dialog running with them and by self-observation and reflecting on observations the manager/researcher can make fruitful discoveries.

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[35] This is analogous to the theory of Argyris, figure 4:5. The first feedback loop represents correcting a mismatch by "more or less of the same", like correcting directions by turning the steering wheel. The second feedback loop involves questioning the governing values, the reasons for the actions: "Should I really be going this way?" The third feedback loop involves the social system from which values stem: "Should I really travel by car, or travel at all?"

[36] There is also the case where findings just confirm a theory.

In classical Newtonian science, a hypothesis or research question is put forth. Then an experiment is arranged, whereupon results are analyzed in order to confirm or reject the hypothesis. In action research on product development projects, this method is not possible to follow since commercial projects are not tuned to satisfy scientific curiosity, but to produce commercially viable results. This is not a problem however, because action research is opportunistic in nature, meaning that one will use what one happens to find. This is the reason for starting with rather vague research questions and then develop them in parallel with the actual research project.

4.6.2 Quantitative research on product development projects

Quantitative methods rely on the identification and election of a few variables out of a myriad of possibilities (based on a theory) that are "measured" by the questionnaires and interviews, which results in statistically processed data that is presented as numbers in the form of tables and diagrams and are therefore said to be quantitative.

Figure 4.6 illustrates the quantitative research situation. By the combination of 23 statements, the graphic representation vividly illustrates what would have been difficult, or perhaps even impossible to show by words alone.

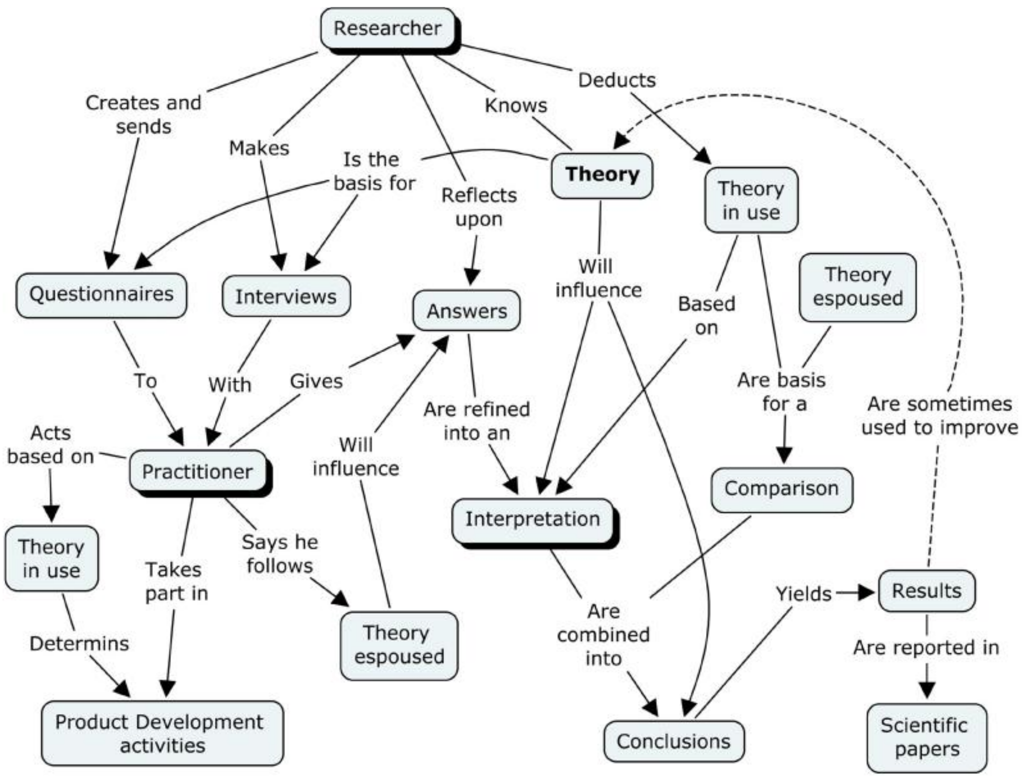

Figure 4.6. Quantitative research on PD projects

The researcher, isolated from direct, personal, observations of PD activities, creates and sends out questionnaires to practitioners based on the researcher's understanding of theory. The practitioners interpret the questions and answer, as they understand the questions. These answers are probably tinted by the theory espoused in the organization that harbors the project under investigation. Furthermore, the interpretation and the conclusions drawn are influenced by the theory known[37] to the researcher.

If the researcher is interested to learn what really happens in the project and what mental constructs govern the project (this is the theory in use) he deducts that from his interpretation of answers that are filtered through theory espoused.

A large part of the respondents usually refrains from taking part in the investigation. The answers from those that care to answer the questionnaires are subsequently analyzed with statistical methods. It is commonly felt that this safeguards against subjectivity, which is perceived as something unwanted.

There are two principle modes of sending out questionnaires, figure 4.7. One can send questionnaires to many companies targeting one person per company, or send questionnaires to a few companies but target several persons per company. The im-

[37] This is his orientation, see section 3.7.3 Aim or purpose of strategy.

portant difference between the two modes is that in the first case, one obtains a single measurement of each unique object, and in the second case, one obtains many measures from each of a few objects.

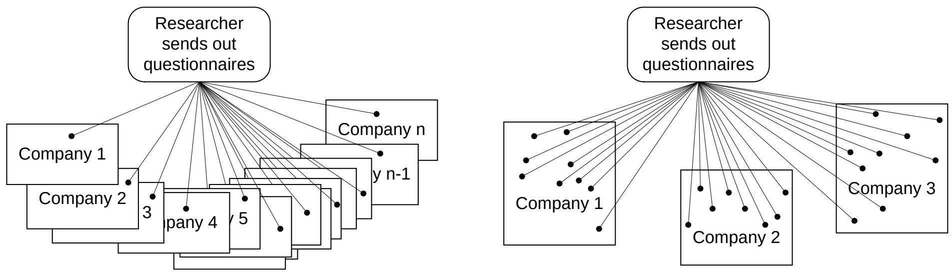

Figure 4.7. There is a quality difference between sending questionnaires to one person per company compared to sending to many persons per company

Questionnaires are attractive to many researchers, because they represent a speedy and cost/labor effective way to collect data from large samples. If however, when reviewing the literature it is found that little is known about a particular area, a qualitative approach is best used first (Marshall 2005).

A questionnaire can be a useful data collection tool where the following conditions are met (Marshall 2005):

1. The target audience can be clearly defined and identified
2. The majority of respondents know what is asked of them
3. The focus of the analysis is numerical i.e. the questionnaire yields quantitative data

Quantitative methods per se are not inclined towards design. Their primary purpose is not to develop and improve practice, but to confirm or reject a hypothesis.

The same goes for interviews, but here the researcher has the opportunity to follow up on answers that seem to need clarification. Interviews can differ from questionnaires in as much as results from interviews need not be presented in the form of numbers but can be given more akin to what is usual for qualitative methods.

4.6.3 Difficulties with the quantitative approach

It is claimed that with careful planning, questionnaires can achieve good response rates and provide anonymity; the latter may encourage more honest and frank answers, than interviews. Because it has been found that when performing telephone interviews, interviewer intonation may affect the outcome of yes/no or agree/disagree surveys and so produce a larger number of positive responses than expected (Eaden et al 1999). Further, interviews can be problematic since "… detailed analysis reveals the interview not simply as an opportunity for knowledge to be transmitted … but rather as an interactional accomplishment in which knowledge is constructed by interviewer and interviewee during the course of the interview. Interviewers are no longer simply conduits for answers but rather are deeply implicated in the production of answers" Schneider (2000).

It can be seen from figure 4.6 that with quantitative methods the researcher is isolated from project activities as all information is filtered through the practitioners' understanding of the situation. Thereafter information is again filtered, but this time through the researcher's understanding or interpretation. Therefore, one apparent weakness of the quantitative method compared to qualitative methods, is that theory in use, and other information, might go totally undetected because the researcher is isolated from what really happens in the development project (Davis 1998). One has very little basis for a sound decision as regards how to improve theory with the aim of achieving improved practice.

Although well designed (Rowley 2004):

- Questionnaires are blunt instruments, as only that which is asked will be answered.
- The researcher must second-guess the respondent and very little qualitatively new information is gained.

Other disadvantages are (Marshall 2005):

- The researcher generally has no idea if the questionnaire was filled in by the respondent it was meant for;
- If there are confusions caused by the questionnaire the researcher cannot clarify these;
- There is little flexibility for respondents to present their own perspective on issues unless there are several open questions.

Questionnaires can give rise to very poor response rates yielding non-respondent bias. In general, the lower the response rate the higher the probability of non-response error (Eaden et al 1999). Poor response rate can lead to bias because some groups are less likely than other groups to fill in a questionnaire (Williams 2003). A non-response rate of higher than 10% may bias the results (Marshall 2005). If direct mail surveys are used, every effort should be made to obtain returns of at least 80 to 90% or more, and lacking such returns, to learn something of the characteristics of the non-respondents and especially so if the response rate is as low as typically 40 to 50% (Tung 2000).

As an example: Except in unusual circumstances, surveys are not considered for publication in CMAJ, Canadian Medical Association Journal, if the response rate is less than 60% of eligible participants, because at response rates of less than 60% it is very difficult to interpret the results (Huston 1996).

There are several tactics described in the literature of how to increase response rate:

- Simplification of the questions (Eaden et al 1999),
- Shorter questionnaire (Edwards et al 2004),
- Small monetary incentives (Engle and Hunton 2004), and
- The use of postage stamps both on the outgoing and return mail (Glascoff 2001).
- Paying out money beforehand is much more effective than paying afterwards (Downes-Le Guin et al 2002).

However, the following actions were not associated with increased response rates (Kellerman and Herold 2001): pre-notification of survey recipients, personalizing the survey mail out package, and non-monetary incentives.

4.6.4 A small survey

A small survey (see Appendix 10) of PD articles published Jan 2000-July 2005 and pertinent to product development, reveals much lower response rates than deemed necessary for reliable research, figure 4.8.

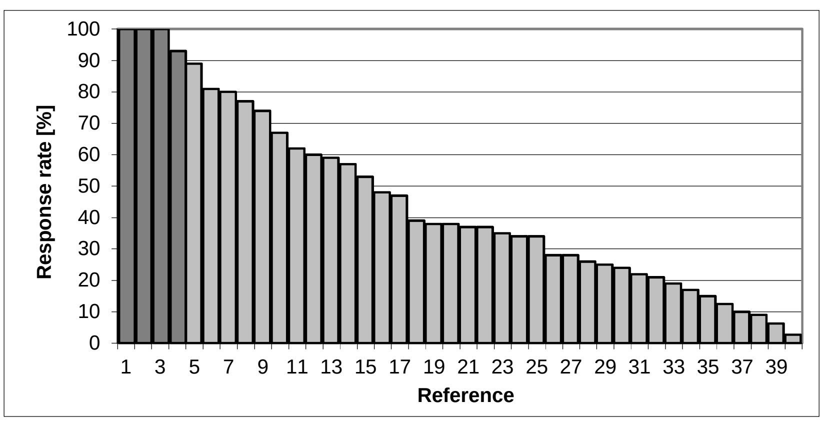

Figure 4.8. Response rates reported in PD literature January 2000 – July 2005. Personal interviews are dark grey and mailed questionnaires are light grey

Some of the previously described methods to increase response rate were used in the surveyed articles; for example giving away a book or an interesting article to respondents or formulating the personalized accompanying letter to give the impression that the respondent's boss had ordered the respondent to participate in the survey. Another trick was to place telephone calls with potential participants and to mail questionnaires only to those that agreed to participate, thereby boosting response rate. These methods of manipulation can lead one to question the reliability of results.

In the surveyed articles, data was collected through personal interviews, telephone interviews, and mailed questionnaires, table 4.3. Only in seven cases were there more than one respondent per company.

Total number of articles	**40**
Mailed questionnaires	35
Personal interviews	4
Telephone interview	1
Single source	33
Multiple source (2-5 people)	7

Table 4.3. A survey of recent PD articles (Appendix 10)

It is interesting how often researchers rely on only one respondent per company. That person is often the managing director, because "that is the most knowledgeable person". Which by today's standard must be said to be an old-fashioned and ill-informed view and besides, how does the researcher know that it really is the manager filling in the questionnaire?

The assumption in quantitative research that a multitude of answers safeguards against subjectivity is perhaps based on the idea that by having many answers, all of them totally subjective, the subjectivity can somehow be washed out by aid of statistical analysis. This idea would be sensible if all research objects were look-a-likes. Unfortunately, they are not. The idea used is like measuring the resistivity of Cu many times (multiple source per item) to improve accuracy compared to measuring the resistivity once (single source per item) for Cu, Fe, Al, Au, Zn, Hg, Li, etc, and then take the average value as the resistivity of metal.

The common notion that quantitative methods, especially questionnaires, are more objective than qualitative methods is a bit odd as the primary judgments (how does this question fit my every day experience of product development activities) are, in the quantitative case placed with the respondents who are the least knowledgeable of theory. While in qualitative research the researchers, who are the persons most responsible for interpretations are in the field, observing, exercising subjective judgment, analyzing, and synthesizing, all the while realizing their own consciousness (Patton and Appelbaum 2003).

Bennis and O'Toole (2005) write, "When applied to business where judgments are made with messy, incomplete data – statistical and methodological wizardry can blind rather than illuminate".

Porter (1995) in his "Trust in Numbers" argues that it was *quantification as a technology of distance* that gave quantitative methods their prestige and status (Bower 1998, Forman 1995A, 1995B). Some of Porter's claims were challenged by Levy (2001) but he agreed with Porter that "…the question of whether quantification replaces judgment …There are no doubt that there are many cases in which this is so, even intentionally done so as to obfuscate."

4.6.5 Qualitative research on product development projects

Action research is a qualitative research method. Here the aim is to capture a deeper, first hand, and therefore untainted (by others) understanding of the researched object with an ambition to improve practice. Action research has a design inclination as it contains an element of improving on a system or of creating a better system.

In the case of product development, this means improving on theory with the aim of assisting and guiding the practitioner to, in some sense, a better, more efficient way of developing products.

Similarly to figure 4.6, the complexity of the AR/IAR research situation is illustrated in figure 4.9, in what would have been difficult or perhaps even impossible to explain in words alone.

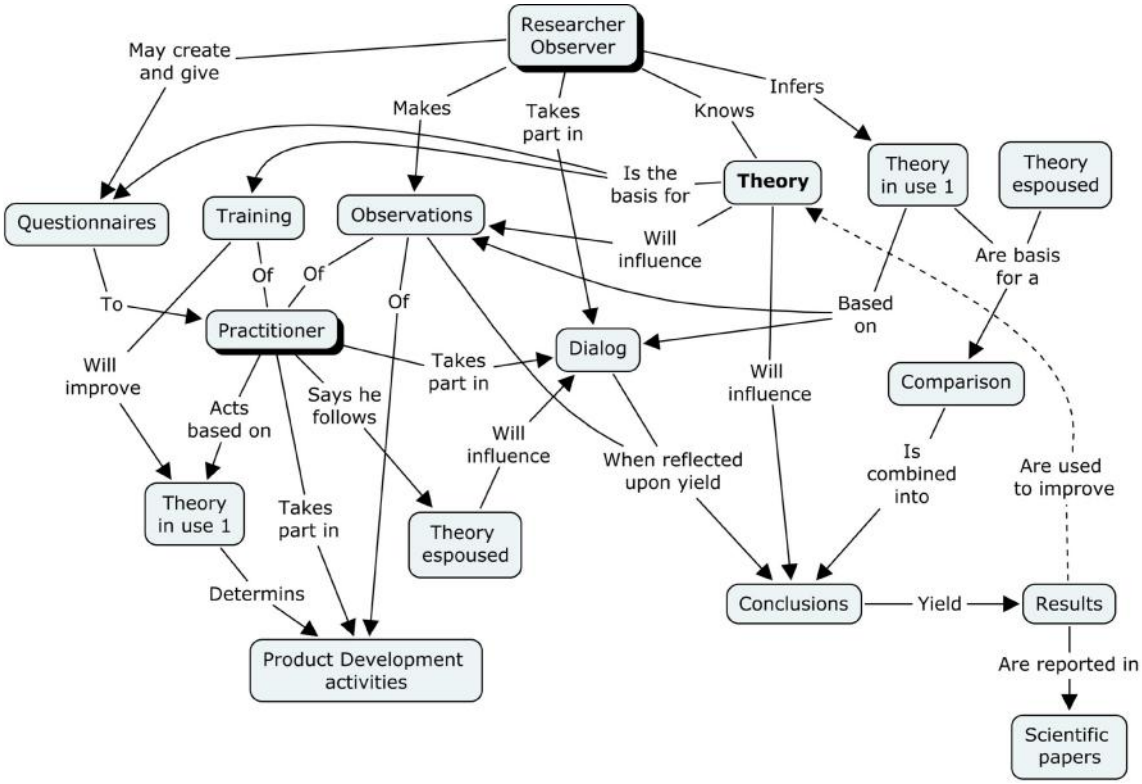

Figure 4.9. IAR or AR depends on researcher's presence. The processing of answers to questionnaires is not shown, as opposed to figure 4.6

As seen from figure 4.9, the researcher-observer can perform some quantitative research by aid of questionnaires and interviews but most impressions will come from direct observation of practitioners and activities, including documents and other artifacts in the project as well as the dialog that the observer may have with practitioners. In this way, the qualitative researcher gains entry into areas that are not available to quantitative researchers (Davis 1998).

Since the researcher is directly observing actions, there are many opportunities to infer a theory in use and to compare that to the theory espoused. There is also the possibility to clarify any inconsistencies with the practitioners through an ongoing dialog.

For example, if a practitioner in dialog with the researcher refers to theory that is incompatible with observations that the researcher has done of the practitioner in action. Then there is good reason to assume a discrepancy between theory espoused and theory in use. This can be investigated further (observations, dialog, questionnaires, etc) and a more correct picture of the theory that guides action, which is the theory in use, can be associated with project performance and other project characteristics of interest.

In this way, the theory in use is identified and evaluated. If there is reason to believe that a better, more suitable theory exists, that theory can be implemented through training of practitioners. This is shown by an arrow from theory to training in figure 4.9.

In PAR the researcher actively participates which is shown in the lower left corner of figure 4.10. It makes the researcher a member of the shared subjectivity[38] of the team. This is the most rewarding research position as it gives access to all parts of the project and especially so if the researcher is project leader.

[38] Section 4.1.1 Subjectivity in a product development team

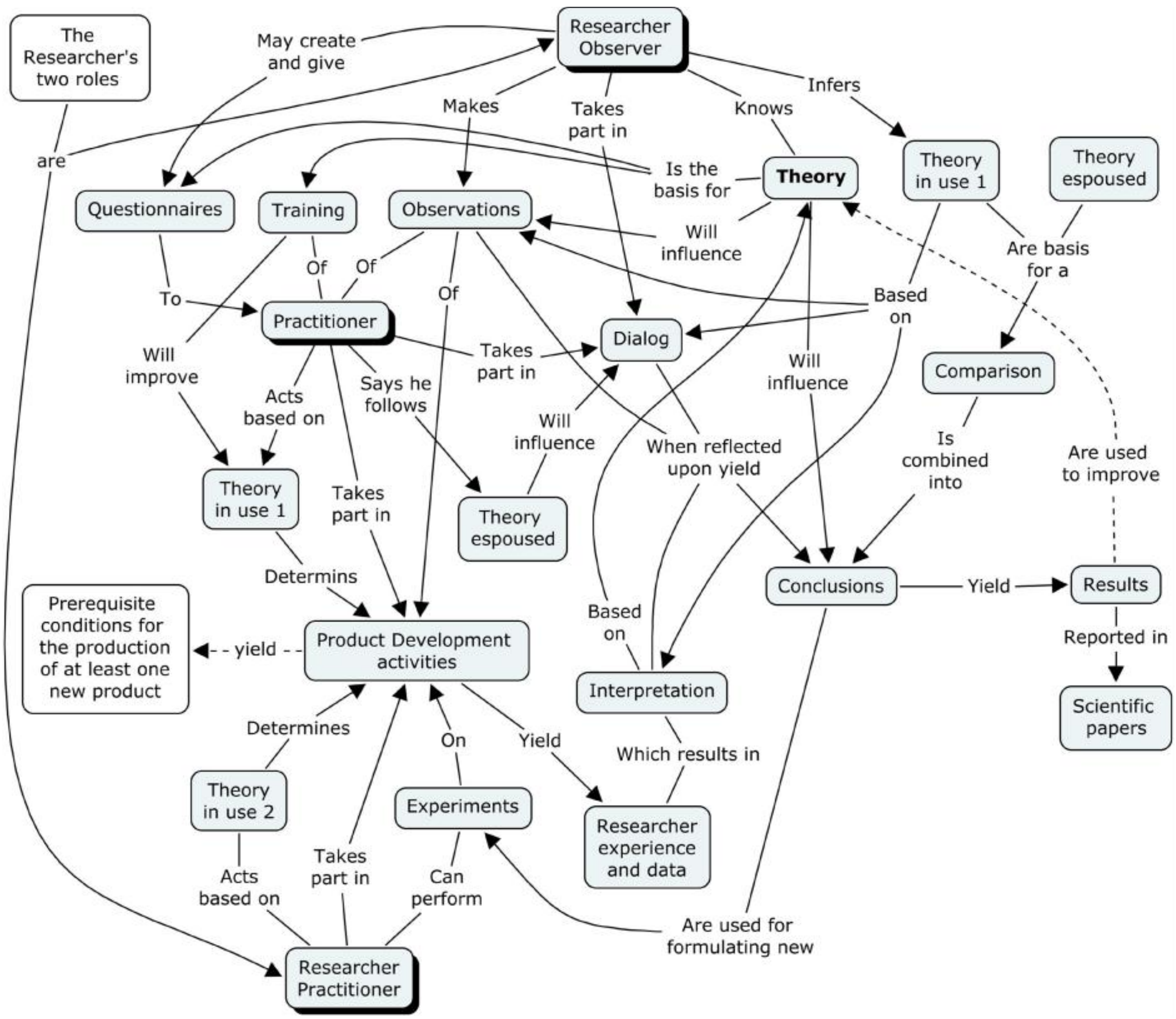

Figure 4.10. The PAR research situation. The processing of answers to questionnaires is not shown, as opposed to figure 4.6.

It is possible in PAR to perform some quantitative research (questionnaires and interviews) but the emphasis is almost completely on participation and direct observation. Note that there is a possibility to perform experiments on the project from the PAR position.

As can be seen in figure 4.10, there are several loops, e.g. theory – training – practitioner – theory espoused – dialog – conclusion – theory, theory – training – practitioner – theory in use 1 – product development activities – researcher experience and data – interpretation – conclusions – theory, and researcher – theory in use 2 – product development activities - researcher experience and data – interpretation – theory in use 1 – researcher, making this a complex system (Richardson 2005). Figure 4.10 should also give an impression of how loops are nested in each other, sharing partly the same pathways, making it very hard, or impossible to separate cause from action. A further complication, omitted from figures 4.6, 4.9, and 4.10, are personal ambitions and office politics.

Another source of complexity is the multitude of multilevel "forces" such as costumers, natural laws, users, management, production process demands, etc, acting on a product development project (Kolenda 2003). It is therefore impossible to study this system by varying one variable while keeping the others constant. What one can do is create small inputs to the system and then study effects. Further, PD projects often are in the un-ordered, complex part of the Cynefin[39] model, where action is probe-sense-respond. To study such systems the researcher must be almost constantly present in the system.

In PAR, the researcher-practitioner is using himself as a sensing probe for gathering observations. It is necessary, in this role, to be sensitive in order to perceive the actions of, particularly, the shadow system. It is a question of seeing that which cannot be seen by the eyes (Musashi 2001). However, what one observes depends on ones orientation (Richards 2004). Therefore, each researcher-practitioner will perceive different parts of what appears to happen, since each team member carries their subjective part of the project.

The project leader-manager is suitably positioned to perform all kinds of experiments and observations. The project can serve as a laboratory (Styhre and Sundgren 2005). The project leader-manager is not only knowledgeable of all parts of the project and all roles played by team members but is also often involved in a political play that team members often are more or less unaware of. It is part of the project leader's role to impose theory in use upon the project so there really is an almost ideal situation here for inferring theory in use and to change that theory if necessary.

4.6.6 An enhancement to IAR/PAR

Action research is traditionally performed on organizations of a permanent nature[40]. These can be likened to machines processing input and delivering output in a steady fashion. The cyclic iterative nature (plan, act, observe, reflect) of most action research is intended to yield both interesting theory and improve on the studied organization.

Product development projects are not permanent but temporary, dynamic, complex and unique systems that do not just transform input to output but create unique output through a design process. Therefore, action research on such systems may lack the typical cyclic nature. Instead, findings from one project may be carried into the next project and used if appropriate to improve on that project.

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[39] Section 3.5 Order and un-order

[40] Section 4.2.1 IAR – Insider Action Research

- In the study of Cases 1 and 2, it was found that it is possible for a researcher who has been in an ongoing project to go one step further and *study the project after its completion* with the aim of making useful findings that can be brought into future projects.

Although scientific discussions took place already at the time of the projects, the basis for the studies are artifacts (minutes of meetings, diaries, timelines, reports, CAD files, etc) and recollections based on the artifacts. We can call this the material. By studying relevant parts of literature while reflecting upon the material, somewhat of a dialog with literature will emerge. Findings, ideas, and hunches are concurrently discussed in a scientific community. This is illustrated in figure 4.11.

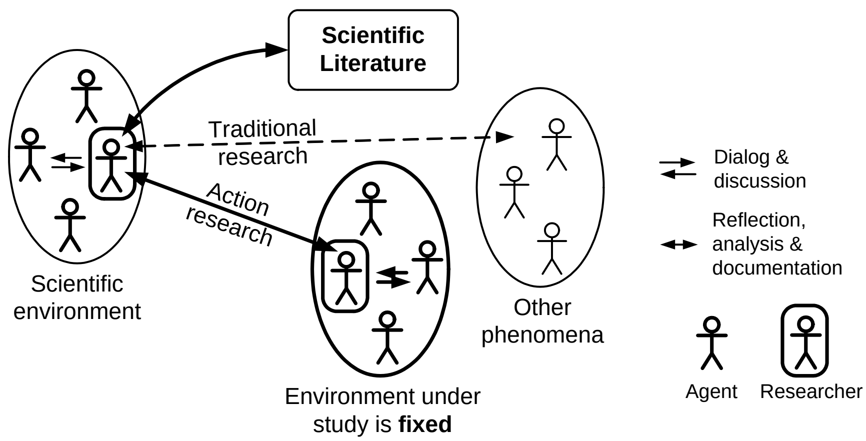

Figure 4.11. The modified IAR/PAR method used in the study

By using concept maps to picture the research situation, figures 4.6, 4.9, and 4.10 – which is new to the knowledge of the author – we become aware of a complexity, involving feedback loops, that would have been very hard, if not impossible, to comprehend or describe in words alone. Further, it was found that concept maps are useful for dissecting a situation, as a starting point for discussions, and for describing a research situation.

For example, the concept map in figure 4.6 shows how the researcher using quantitative research methods is isolated from PD activities. While, in contrast, the AR/IAR/PAR researcher will have direct observational contact with project activities, which is visible in figure 4.10. The concept map shows how, in this way, the qualitative researcher gains entry into areas that are unavailable to quantitative researchers.

5. Case 1 – Becoming a rack producer

The research method of this treatise is insider action research (IAR), which by its very nature involves a participating researcher. There is no detached researcher observing from outside. The reporting of such case studies by necessity takes on a narrative style, because that is the best way to give the reader an inside view without being lost in details (Björk 2003). Therefore the detached "the author" in the following case description becomes "I".

5.1. Introduction

This is a description of weeks 14-23 in 1998 of the first phase of what would grow naturally into a larger business case. The setting is Prosolvia Research & Technology AB, a subsidiary to Prosolvia AB. There were 650 employees at Prosolvia AB, with about 350 of them directly occupied with industrial software development, mostly virtual reality (VR) software, making Prosolvia AB a leading provider of *virtual reality solutions*.

Prosolvia Research & Technology AB, PRT, had about 145 employees of which circa 45 were mechanical analysts and almost as many were design engineers, a few production-engineering specialists, and the remaining were software specialists.

A few weeks prior to this, our company vice president had been on a sales trip in southern Sweden and had visited, among others, Verkstäderna Weibulls AB in Hässleholm, Sweden. The company will be referred to as just "Weibulls" in this treatise. Somehow, there had developed a kind of affinity between the two company representatives at that meeting, so when Weibulls' managing director later on wanted help he came to us, resulting in this project.

5.2. Background

Weibulls produce chassis frames for busses, trucks, and construction equipment, by welding together steel beams and tubes, sand blast them and apply some kind of surface treatment. At the time, they were planning to move some of the production capacity with their customer, Volvo Truck AB, to Poland and build a production plant just outside of the Volvo fence. However, they felt a bit limited by just producing vehicle frames. New technology, like the new Volvo Bus space frame consisting of short pieces of corrosion resistant rectangular steel tubes welded together was perceived as a threat, because it could be produced by almost anybody and did not need any surface treatment or heavy equipment for its production.

At Weibulls, they were looking for ways to grow into new markets. Looking for new products, management at Weibulls searched for a product that should be welded together, have a weight of 100-1000kg, and have sales volumes of a few tens to a few hundred units per year, gaining large series economy through commonality in parts.

Their eyes had fallen on racks[41]. A rack is a steel pallet designed to carry stamped sheet steel parts (fenders, body sides, hoods, etc), windows, engines, etc from their production plant into the assembly line of the automobile maker.

Weibulls had consulted with Modular Management AB, a specialist in modularization of products, and thereby been supported in their conviction that racks would be a suitable product. A contact had also been made with the division of transport technology at Chalmers University of Technology, CTH. At Weibulls, they had made a few sketches of rack modules, but perhaps felt that they lacked real development capacity and therefore they had turned to us at PRT for help.

5.3. Project execution

This project started on Monday afternoon, March 30, 1998, by my department manager telling me that there was a company in Hässleholm called Weibulls AB and that they wanted to develop racks. Further, he told me that modularization was an important ingredient and could I please contact the manager of Weibulls and arrange for a meeting?

I called Mr. Axel Leijonhufvud, managing director of Weibulls and arranged for a meeting the following week. Thereafter I purchased a book on modularization, reportedly written by one of the parties involved (Erixon 1997), and began to read.

5.3.1 Week 14: Getting a grip on the situation

On Monday 1998-03-30[42] I prepared myself for the meeting with Axel Leijonhufvud, by making a MS Project Gantt chart based on our understanding of the assignment as it was expressed in our quotation to Weibulls, figure 5.1.

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[41] There are more than 60 000 racks owned by Volvo Car Corporation used for transporting goods from suppliers to the Volvo assembly plants.

[42] In this thesis, dates will be given in the format prescribed by ISO 8601.

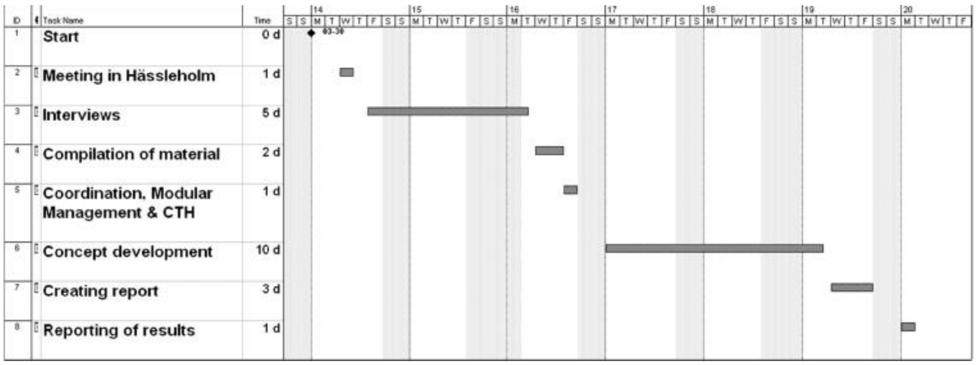

Figure 5.1. Expectations on Monday before meeting the customer on Wednesday

The Gantt chart is illustrative of how the job was perceived at PRT: a meeting with the customer first, then interviews to collect information, compile the material and coordinate the findings with Modular Management AB and the contact at Chalmers University of Technology, that Weibulls had developed. Thereafter would follow a couple of weeks of concept development whereupon a report would be written and results reported. At this stage, it looked like an easy job!

Wednesday morning, 1998-04-01 07:20-10:00, I drove my car the 240 km from Gothenburg to Hässleholm and met with Axel Leijonhufvud. We made the obligatory tour around the factory while Axel informed me of facts of the production facilities, suppliers, capacities, plans for the future, oddities, etc.

On occasions like this, one is overwhelmed by impressions that are processed and stored away by the subconscious mind. Things like unused empty shop space, if the shop floor has been swept, how the parking area is arranged (are there parking slots reserved for upper management?), are workers working or reading the paper, are there empty pallets and cardboard boxes laying around, what is the pace of the machines, are there many forklifts driving around, how is the ventilation working, walking by a billboard with quality statistics, what does it say; are lavatories clean, when were the walls painted, are the floor tiles worn, how are people communicating, are they sitting in isolated rooms or in an office landscape, are people smiling, how do they seem to get along, how are they dressed, how do they make their coffee, how do they behave at breaks, etc, etc.

Arriving at the office, we sat down at a round table in Axel's room and he spread out large drawings of the rack idea that they had been working with. It did not look like much. The printout was all right, and as such, it made the idea look better than it was.

It should be noted that I was there as a consultant project leader, a gun for hire, you might say. A difficult situation since I was serving two masters; the customer and my employer. Because this was hopefully the beginning of a good business relationship, I kept in my mind questions like:

- What is the customer aiming at, what are his motives?
- What *must* be achieved?
- What are the deliverables?
- What will make the customer (and the user of the product) satisfied in the long run?
- How will our achievements be measured?
- What is really, really, important and what is less important?
- Which persons are important, who make the decisions, who are the key players?

In addition, there were thoughts on the time schedule and staffing; questions such as what headcount is needed and for how long? What competence should each project member posses? And always in the back of ones mind: what risks and opportunities are there? Especially the risks, their cause, risk events, consequences, probabilities, cost, and possible evasive actions.

Mr. Bo Ahlberg, Weibulls sales manager joined us and told me of their contacts with Volvo. Axel told me that they were contemplating acquiring a rack producing company called JIWE with a plant in Arendal close to Volvo Torslanda (assembly plant) in Gothenburg and one in Olofström, close to the large stamping facilities that Volvo operated there. Further Weibulls had just received a request for quotation from Volvo Transport AB for a large number of racks. Now the question was, is there enough time to prepare a serious quotation? If there is, what rack should we offer?

After a little more talk Axel showed me the office, they had reserved for me. It was a dull looking room with nothing more than a desk and a chair and a telephone that had been disconnected. They apparently expected me to sit and work in that environment, completely geographically isolated from my home office and from the Weibulls staff.

Then I met with Mr. Ulf Månsson one of two design engineers who's job it was to design welding jigs and other production equipment. Ulf and I had a short discussion about the drawings of the rack proposals they had made so far. It was clear that they had not come very far.

Driving home, I contemplated impressions and all that I had learned that day. Apparently, ambitions were high, but did they have the power to follow through? Was there enough time to prepare a serious quotation? The aim was to establish Weibulls as a rack supplier – in that perspective, what was important?

The following day, 1998-04-02, I met with Mr. Lars Johansson, rack purchaser of Volvo Car Corporation, in Gothenburg, to get his and Volvo's opinion on racks and Weibulls' ambition.

I had telephone conversations with Mr. Oskar Falk and Mr. Per Moqvist from the Volvo engine plant in Skövde regarding logistics there and I talked to Mr. Tomas Hollender of Volvo Transport AB, in Gothenburg, which is the company handling most of Volvo's transports. Further, I called Mr. Lasse Lindgren, shop manager at JIWE Arendal, to arrange for a meeting.

By meeting with or just calling these people, I had learned the following about racks:

1. 3D CAD must be Catia[43]. The supplier shall send numerical models to Volvo that Volvo can use in production planning. Production layouts are all 3D CAD.
2. The supplier must be able to develop packaging around the detail part. This implies that Volvo very early in development will give out 3D-models. From this the supplier develops a rack that is delivered to Volvo Car in the form of a 3D model. This model is then used by Volvo production planning.
3. The supplier shall start early in the development of an article and follow the article during its life span and develop its packaging. The main activities are design, manufacture, service, and change.
4. The supplier must also have other customers than Volvo Cars.
5. The number of orders for packaging material is circa 600 per year. Maybe 200 of these are orders for new racks, additional racks, changes, etc.
6. At Skövde (Volvo engine production) they have 3000 engine racks, each carrying 6 engines. All kinds of engines use the same basic rack.
7. Volvo Car climate units demand 1000 racks.
8. In some cases the need is as low as 30 racks. It all depends on numbers and size of the part.
9. A container is loaded full with racks. The floor space is divided in 4, 5 or 6 parts.
10. Trucks are loaded with collapsible racks in order to facilitate easy return transportation, which can be by another car and transport company.
11. Empty racks are often kept outdoors.
12. The largest load is when handled by forklifts. Operators drive like crazy.

[43] This was during the period of migration from Catia v4 to v5 in automobile industry.

13. The Volvo Car goods are volume goods. Weight is of no concern yet, but environmental considerations have started to become an issue as new models for estimating environmental impact are beginning to be used. Within the nearest future weight will become an issue of environmental concern.
14. Surface treatment shall be hot dip zinc in all cases where rusty water is absolutely prohibited. In other cases two layers of lacquer, corrosion protection class M3 is sufficient.
15. NedCar tried aluminium. It did not work because the center of gravity became too high and the goods tipped over during transport. Fittings can be made of aluminium though.
16. Often 4 mm mild steel tubes and sheet material is used.
17. At high frequency use there can develop fatigue failure in welded joints. Therefore in these racks t = 5 mm is used.
18. Ford Motor Company use modules. One mid module and one or two gable modules. Different lengths are accomplished by use of 3-4 different modules between gables and midsection.
19. The bottom base section must have holes for forks in all direction and guides for the forks deeper in the rack.
20. The Volvo catalogue of packaging materials has 674 pages.

Friday morning, 1998-04-04, saw me going to the JIWE plant at Arendal, to meet with Mr. Lasse Lindgren, the plant manager. This was the company that Weibulls were negotiating an acquisition of, so as a representative of a new possible owner I was given a fair treatment. At Arendal, they were mostly servicing racks, but also building some new ones. We walked through the workshop and Lasse informed me of the business situation and of the peculiar business logics of racks.

Back at the office, I called Kent Sjöberg, managing director of JIWE Mekan AB in Sölvesborg, the mother company, for additional information.

My spontaneous impression from witnessing rack production was that there was too much cutting of tubes and bars, too much welding, too much grinding by hand tools, too heavy and clumsy designs, too much drilling and cutting threads for screws and too little use of high strength steel and rational production methods.

That afternoon I sent a fax to Axel Leijonhufvud informing him of my findings and discussing rack design and production, which went something, like this.

> Suppose that it takes 4 weeks to design a rack from bottom up and that 25% of the 200 rack orders are for new racks. Further, suppose that there are 45 working weeks in a year. This implies that Weibulls, as a sole supplier, must have a development department of circa 50*4 weeks/45 weeks = 5 engineers. For the additional

150 orders there is a need for 2 engineers, making a total of 7 design engineers and as many Catia workstations. For customer contacts and purchase of parts there is a need for 1+1 = 2 employees. Making it a total of at least nine additional employees above what Weibulls has today in order to cater for Volvo Cars alone as a sole supplier (production needs not counted).

The first Gantt scheme, figure 5.1, was based on the assumptions in the offer Prosolvia Research & Technology AB had made Weibulls AB that the job would consist of: perform interviews, gather information, coordinate Modular Management and CTH, create suggestions for a modularized rack, give a first proposal for rules of modularization, write a report, and report the job.

After the first meeting with Axel Leijonhufvud that opinion had changed to something like this, the main points being:

- Handle the business of the P26 torpedo beam rack (the rack that Volvo wanted a quotation for from Weibulls),
- Future modules,
- Service of racks,
- Production planning,
- How to structure, that is how to divide activities between Olofström, Gothenburg (Arendal) and Hässleholm.
- Development process: personnel, computer equipment, etc,
- Volumes,
- Competitors,
- Patents,
- Other solutions and
- Check if there are any branch organizations.

This was quite a turnaround of the situation. I would have to discuss this with Axel. I made a new Gantt chart, figure 5.2. This was a very, very tight plan for cooping with the request for quotation (RFQ) from Volvo Car, called P26 torpedo beam that Weibulls had received.

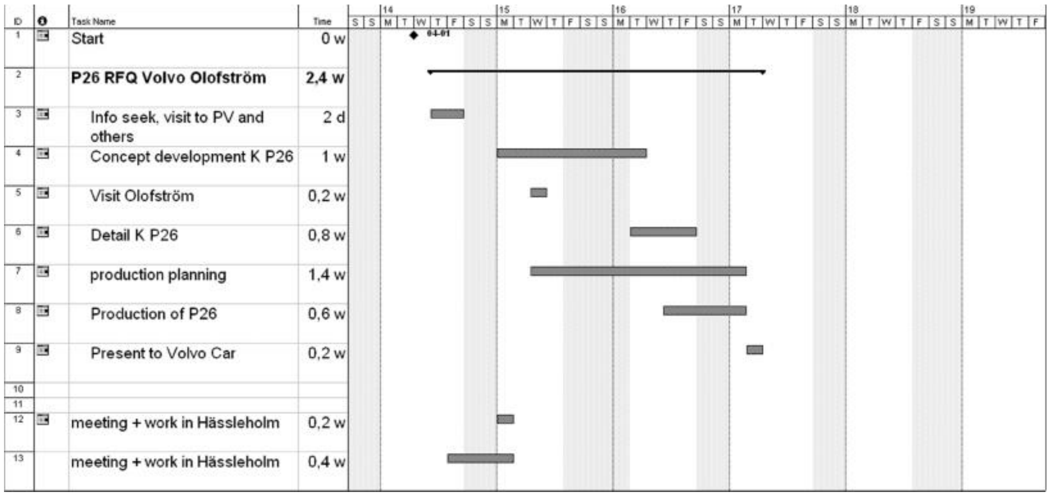

Figure 5.2. The plan after the first meeting with the customer: everything had changed compared to the first plan of four days ago

I spent three hours on Sunday 1998-04-05 preparing for the following week and my meetings in Hässleholm with Axel and Ulf, the design engineer. I sent a fax to Axel informing him that I would arrive Monday morning, but that I had to be back at my office on Tuesday, but could be back in Hässleholm on Wednesday. That took care of that dreadful office room they had reserved for me at Weibulls. I certainly did not want to sit there.

5.3.2 Week 15: Development starts

Monday morning 1998-04-06, a long drive from Gothenburg to Hässleholm and meeting with Axel Leijonhufvud and Ulf Månsson. My intention with the meeting with Ulf was to start concept design. I had wished for a meeting with all design engineers, production planners, and production managers that would become involved with racks. I would have to be satisfied with meeting with the two design engineers and Axel, only. This was a warning sign that normally I would have acted upon, but it did not threaten our business relation so I let it pass.

The agenda that I had proposed and that we walked through consisted of five main points.

A. We went through the RFQ received so far and I informed the meeting of my findings regarding racks. We discussed loads on racks and dimensions necessary to carry these loads. Then a brief idea generation of Weibulls' racks, how to collapse, how to design the base structure, production methods, suppliers, etc.

B. A discussion of design prerequisites, such as fork measures, the height of the fork when in its lowest position, accelerations and frequencies, rack dimensions, number of travels over the lifespan of a rack, way of transportation, number of forklift handlings: raise, lower, drive over uneven surface, environment outdoors/indoors, temperature, etc.

C. Start the production planning of a typical rack to get a feel for the subject.

D. Suggest contact persons towards customers.

E. Time schedules.

I took up the issue with Axel of the severe discrepancy between my company's quote for this job and how the job had actually developed. We came to an agreement to more or less "drive by the seat of my pants", a situation that I was happy with. After all we had a common understanding of the goal of the project and I was reporting developments to Axel on a regular basis.

Tuesday I was occupied with some idea generation and quick strength of materials calculations and tending to other projects at the office like a production simulation program developed by Prosolvia and a LHMD, light head-mounted display, developed in cooperation with Ericsson and with VR as intended use.

I started Mr. Jonas Andersson, one of our design engineers in the project by having him import 3D models from Weibulls and Semcon AB, a consultants company that Weibulls had used.

Wednesday 1998-04-08 meant tending to my part in the production simulation software called Digital Plant Technology that our sister company Prosolvia Systems AB, was developing. I had time for calling Ulf Månsson at Weibulls regarding patent numbers. There were patents involved of course. Many inventors had put their minds to simplifying transportation of goods. There were rumors circulating that one supplier, MTS, a German company that produced a special "console pillar", a pillar with hinged and automatically folding small hangers like console beams protruding from the pillar, allowing for a very rational loading and unloading of parts, had their design protected by patents. I had to investigate the situation. We also needed, I informed Ulf, a concept design to present to Volvo Olofströmsverken at the meeting that was planned with them.

Thursday 1998-04-09 meant more idea generation and strength of materials calculations and sifting through the catalog from Volvo Transport AB to learn about different racks and packaging materials. All squeezed in between other projects.

Friday was a national holiday.

5.3.3 Week 16: Concept design

Monday 1998-04-13 was still a national holiday, but I worked full time anyway, with concept development using pencil and paper. This is called PAD, pencil aided design in DPD.

On the following morning, I was yet again driving to Hässleholm with new meetings with Ulf Månsson, Rolf Ek and Axel Leijonhufvud. Subjects were the same as in the previous meeting. Things were complicated, what should we aim for, what factors were important? We did not fully understand the business logic. Then came the surprise.

In my meeting with Axel, I brought up JIWE the rack producer Weibulls was negotiating an acquisition of, when Axel told me that no, there would be no deal. Visiting the workshop in Arendal, Axel had suddenly felt that, no they are so bothersome to deal with that we will go alone; we have enough power for that.

The next day was concept design day. Mr. Per Nobring from Semcon Data AB called and said he'd emailed additional CAD files. They arrived late that afternoon. Jonas was compiling the Weibulls' rack.

On Thursday 1998-04-16 I drove to Hässleholm for a meeting. The subject became increasingly complicated as we learned more. Mr. Hasse Nörgård managing director and owner of MiniPart AB participated in our meeting. Hasse had been in the rack business for many years and knew this business well. According to Hasse, bribes were common. There reportedly was a rack producer who owned a nice summerhouse that he never stayed in himself. It was however, often occupied by different parties. This complicated matters even more. We had no intension what so ever of bribing anyone. Hasse saw his company's part in this as a supplier of parts to Weibulls. There is always a need for small brackets, locking devices and elastomer protection bits and pieces.

I reported my, and Prosolvia's part of the project, as well as other findings to Axel. Discussions were long. I drove home late.

The next day 1998-04-17 was concept design only. I now had two design engineers working on the project at the PRT office, creating 3D-models from the pencil sketches I gave them. I had an idea, called a large producer of cold-formed tubes and profiles, Heléns Rör AB, and talked to sales representative Mr. Peter Herenstam. I wanted to investigate the economy of using custom-made profiles for the racks.

I called project manager Mr. P O Möller from Volvo Cars to arrange a meeting, but had to be satisfied with meeting the person responsible for logistics in the project, Mr. Magnus Salander.

5.3.4 Week 17: Rack design

Monday morning 1998-04-20, there was a meeting at Volvo Cars headquarters with Magnus Salander, responsible for project logistics. This was very interesting. 3D-models of racks were needed because prior to building production facilities for a new car project, production was simulated. An avatar was unloading the rack and the level of fatigue was calculated from the simulation. Also handling of the rack by forklifts was simulated. It was clear that in future, rack suppliers would have to be much more competent than at the present.

My design engineers Mr. Jonas Andersson and Mr. Kari Tuiski were busy building CAD models based on my pencil sketches. I had a telephone conversation with Ulf Månsson regarding patents for console pillars and different ways to proceed.

Tuesday 1998-04-21 meant more concept design. For a novel design of a console pillar, I used cardboard that I cut out and pinned by aid of needles in the console hangers centers of rotation. It was a fairly straightforward and simple method of quickly getting forward. It was also an easy way of showing my CAD designers what I wanted. This is called MAD, model-aided design in DPD (Ottosson 1999B).

I had a new discussion with Mr. Peter Herenstam, Heléns Rör AB, regarding custom made profiles and tubes. I also called Mr. Lars Bergström, LBM AB that sells the MTS console pillar in Sweden.

Wednesday 1998-04-22, more rack concept design. We now have CAD models for the "torpedo beam". (Torpedo beam is an Anglicization of "torpedbalk" a Swedish name used at Volvo Car Corporation (VCC) for what could be called firewall upper, plenum upper, or windshield beam). The trick is to design the rack to carry as many pieces of torpedo beams as possible without them making contact with each other.

Thursday 1998-04-23, rack concept design. I reported progress to Axel and sent some printouts by mail.

Friday 1998-04-24, rack concept design. We are building together parts for the torpedo beam rack. I called Ulf Månsson and talked about different rack variants and the upcoming meeting with Volvo at Olofström. I talked to Mr. Magnus Salander, logistics specialist at Volvo Car Corporation, over the phone and decided a meeting next week.

Just before going home, I faxed Axel some miniature printouts of the racks we have been designing.

5.3.5 Week 18: More rack design

Monday 1998-04-27, more rack design and I saw Mr. Magnus Salander at Volvo Headquarters. In an effort to broaden our perspective, I phoned Mr. Peter Johansson, rack purchaser at SAAB Automobile and learned about rack volumes and strategies. Naturally since SAAB Automobile was pressing the large body panels adjacent to the welding shop and also was building much fewer cars than Volvo Cars, their needs for racks was that much smaller.

Tuesday 1998-04-28 and Wednesday, more rack design, and Thursday meeting with Volvo Olofströmsverken, VOV, in Olofström, a long drive across the country.

Representing Weibulls were Ulf Månsson and I. From VOV came Mr. Alf Hansson, production planning, and two design engineers, Mr. Håkan Karlsson and Mr. Krister Andersson.

I presented the following issues as interesting for Weibulls to get clarified during the meeting.

1. What should a rack supplier look like?
2. What does VOV want help with? (Time plans and ambitions)
3. Number of racks per year: collapsible, non-collapsible, small, large.
4. Number of racks per article?
5. Design prerequisites
    a. Fork measures
    b. Fork height above ground when at its lowest position.
    c. Loads, accelerations, and frequencies.
    d. Rack dimensions.
    e. Number of travels during the lifespan of a rack.
    f. Travel length.
    g. Way of transport.
    h. Number of forklift handlings: lift, lower, drive over irregularities, …
    i. Environment outside/inside, temperature, etc.

Handling of goods; what should we think about in order to design an ergonomically sound rack?

Alf stopped me cold, saying we should concentrate on the torpedo beam rack. Therefore, instead of the important questions above we discussed and decided the following.

1. Catia shall be used, and with Volvo settings (which we already knew).
2. Quick responses are *very important*. It often happens that Volvo Car must change some detail in the last minute and then VOV and the rack supplier must be able respond very fast by presenting a suitable solution. This demands that one has Catia resources available. Fast and in appropriate measures.
3. Tolerances of the rack volume is 5 mm.
4. The torpedo beam has new outer measures: 1900*1200 and total height 1430 mm. 7 pillars beside each other and the new total height: 12 beams, giving a total of 84 beams per rack.

Now we raised the question of number of beams on top of each other since we were trying to maximize that number.

5. Number of details per rack is an interesting question.

6. Console pillars are best for torpedo beams.
7. **Weibulls shall present the price** for a/ a “bare bone”rack, b/ a complete rack with console pillars. This is important for the next step.
8. Regarding suppliers of console pillars. LBM AB and their German supplier MTS are troublesome to work with. There are often delays and excuses. They charge for delays that are caused by VOV. “A day costs a week”. Furthermore, all parts are made of steel. This leads to high weight, and further, the consoles must be covered with PUR or some other such substance. Therefore, they have searched for and found another supplier, Tiegler that makes pillars in Spain. These are made largely from plastic which is a plus when parts for interior use are transported.
9. Tolerance for console positions is ± 2 mm.
10. **Weibulls shall give the price** for a torpedo beam rack consisting of: Weibulls frame (sheet metal structure) + console pillars on one side + pillars with fixed consoles on the other side.
11. The request for quotation (RFQ) for torpedo beam rack is due next week, week 19.
12. Surface treatment shall be wet paint or powder paint. Color blue.
13. The tubes shall have drainage wherever necessary.
14. As the forklift driver lifts the rack, he sees the Odette-carrier down to the left and origin for the rack coordinate system down to the right. The corner is the origin.
15. Coordinate system origin must be market on drawings.

5.3.6 Week 19: Detail design

Detail design of a so-called “Weibulls rack” had started at the PRT office. The rack consisted of a sheet steel frame and a profiled sheet steel panel in-between. Further, there were deep drawn corner pieces; all welded together, figure 5.3.

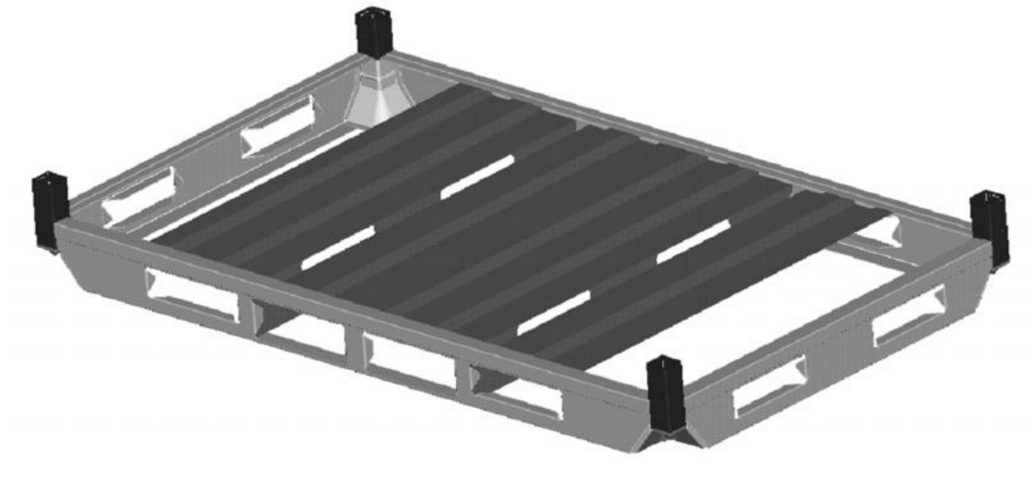

Figure 5.3. A so-called Weibulls rack frame, consisting of a sheet steel structure and a profiled panel in-between with deep drawn corner pieces and welded tubes

On Tuesday 1998-05-05, the detailed design of the torpedo beam rack started. Detail design continued for the week, keeping Jonas Andersson and Kari Tuiski occupied while I spent some time tending to other projects.

On Wednesday 1998-05-06, I met with Mr. Bo Lindberg of AWA Patent, to discuss the patent situation. Bo handed me a huge stack of patent documents that I brought home to the office and slowly sieved through. There seemed to be no pending patents restricting our actions and unfortunately no good ideas to "steal".

On Friday 1998-05-08, I talked over the phone to Hasse Nörgård, Minipart AB. He thought that we were positioning our project correctly and wanted to be of service as a supplier of parts as well as a discussion partner. He told me that a rack manufacturer in Oskarshamn had lowered his bid so much that he would lose 1000 SEK per rack, just to get an order, but lost the competition to a manufacturer in Hässleholm that offered a 20% lower price than the manufacturer in Oskarshamn.

I sent a request for quotation for console pillars to LBM AB, representative for MTS the German manufacturer of console pillars. Most drawings were ready (so that one could build prototypes from them) and were mailed to Mr. Kenneth Zäll at Weibulls. Late that evening I sent the last drawings to Ulf Månsson together with my new ideas of using virtual reality. The background to using VR was the following.

In order to convince Weibulls' customer, VOV, we thought that we needed to build a prototype. That would also serve another purpose besides convincing VOV and that was that it would give the production planners and people in the work shop a learning experience that would result in lots of valuable feedback for fine-tuning the design.

As time was running out, however, there simply was no time for building even prototype press tools, purchase material, organize people, etc. Besides, such an exercise would not come cheap. Therefore, we contemplated using VR instead. The automotive suppliers fair in Gothenburg the following week would be a suitable date for presenting the rack.

Prosolvia AB had developed software for manipulating VR-parts while in the cave44, just as if it had been "real" parts. The idea now was to transfer the rack to VR models and have the Volvo people load/unload virtual torpedo beams onto the virtual Weibulls rack.

I knew that 15 minutes in the cave was very impressive for someone who had no previous experience from VR. I made two different two-hour reservations of the cave for the following week and started to search for someone competent and willing to transform the Catia files to VR-files and upload them to the VR computer. That done, we would just have to summon up the audience.

5.3.7 Week 20: A first peek in the cave

Monday 1998-05-11 meant using all the weight I had with the organization to persuade someone to help with the VR file transformation. On Tuesday, I finally succeeded and faxed to Axel Leijonhufvud that there were two reservations made but several important people could not come so possibly we should postpone the VR activity to the following week? Axel said no, he would be in Gothenburg on Wednesday, so "lets do it then!"

Tuesday 1998-05-12, I met with professor Mats Johansson at CTH regarding transportation and racks, trends and such. Nothing memorable. The quotation from LBM AB arrived and I forwarded it to Mr. Kenneth Zäll at Weibulls.

Wednesday 1998-05-13 at 11:30 Axel arrived and half an hour later Mr. Lars R Johansson, purchaser of racks from Volvo Car Corporation, and Mr. Ingemar Söderlund, a rack designer that Lars Johansson had brought with him. We had a light lunch and then a visit to the cave for to study the Weibulls rack.

Watching a VR image is always fascinating and afterwards Axel gave his view of rack development. Lars R. Johansson expressed a wish for a coordination of activities between Weibulls and Volvo Car Corporation, especially in view of the coming new Volvo standard for racks. We decided that the next meeting should be in exactly two weeks time.

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[44] A cave is a room where animated images are projected onto all walls and the floor in order to create an illusion of an immersive 3D environment = Virtual Reality, VR.

Lars and Ingemar went back to Volvo and Axel and I discussed the situation and planned for the great presentation that we now had decided should be in week 22. Axel wanted me to handle Weibulls' contacts at VOV and Weibulls' quotation to VOV for the torpedo beam rack. It was important to convey to VOV all the extras that followed, such as low weight, easy maintenance, right quality, development potential, etc. But the quotation should go through Bo Ahlberg, the sales manager at Weibulls. Axel had learned that VOV wanted to build prototypes. That was something worth investigating since that could bring in some money. Building one-of-a-kind racks did not bring in much money but could be very profitable due to the high margins possible. Further, I should gather and systemize information regarding the situation as a whole, as well as rack specifics.

We talked about whom to invite in week 22 and decided on the following agenda:

1. Demo of the torpedo beam rack in our VR cave, with beams and loading beams.
2. Demo of the rack positioned in a robot cell at the Volvo assembly plant.
3. Discussions regarding racks
    a. What Weibulls have done so far,
    b. Basic measures,
    c. Can surface treatment be different for different parts of the same rack? Substitute paint with electro zinc plating?
    d. Machines to produce racks.
    e. Life Cycle Cost, LCC
4. The different roles of Volvo and Weibulls.
5. Console pillars
    a. Patent situation
    b. Players: LBM, Tiegler
    c. A solution of our own from Småland[45].
    d. Developing a Swedish solution. Help from Volvo?
6. Next meeting, etc.

Thursday 1998-05-14, I told Axel we had three reservations of the cave for week 22. The following day, a Friday, the invitation for the presentation of the new rack in

[45] Småland is a province of southern Sweden known for its industriousness and extreme cost-consciousness. Especially within the triangle of Hillerstorp, Gislaved, and Anderstorp. The municipality of Anderstorp is said to have more registered companies than inhabitants.

Prosolvia's cave was sent out. It said that we will show a Weibulls prototype rack, test loading/unloading beams from a rack (even with a robot), give an account of Weibulls' competence, and discuss how to proceed from here, what we can do in cooperation and Volvo's intentions.

That Friday I compiled a document called "Weibulls' rack project, future activities" beginning with: "This project aims at making Weibulls a leading producer of racks. This implies developing, manufacturing, selling, and servicing racks of foremost steel". The document continued by laying out a strategy and its economic consequences. The primary intention was to use the document for to collect and systematize my own thoughts. The secondary intention was to use the document as bases for my employer's business with Weibulls.

5.3.8 Week 21: Tidying up

This was a low activity week consisting of taking in quotations for rack parts, distributing the last few drawings and calling all the persons we had invited to the great presentation in week 22, to check that they had received our invitation and that they would like to come.

Less positive was my effort to enthusiasm someone at our sister company Prosolvia Clarus AB to help with preparation of the rack demo. They all seemed too occupied with writing demos for the sales department than preparing something real for real potential customers.

5.3.9 Week 22: The moment of truth

Monday and Tuesday saw from my side increasingly desperate efforts to kick the VR-software specialists into action.

We sent out an agenda to all invited.

Wednesday 1998-05-27 at 11:00 the meeting started. Our guests were Alf Hansson, Jörgen Håkansson, Jossip Matailja, Krister Andersson and Håkan Karlsson from VOV, Curt Jakobsson, Volvo Truck Components, Karl Otto Wikmark, Volvo motorfabrik Skövde, Richard Schönmeyr, Lars R Johansson, Magnus Salander, P O Möller, Volvo Car Corporation, and Hans Håkansson, Syneco AB the mother company of Weibulls, Axel, and me. It was quite a gathering of Volvo people we had summand up.

The meeting followed the agenda.

1. *Introduction with a presentation of each other and Weibulls AB.*

A presentation of Waybills' opinion of the future as concerns racks which can summed up as some key issues.

a. CAD, VR, simulation, parallel activities (concurrent engineering).

b. LCC, life cycle cost is most important.

c. Environmental impact,

d. Modularization.

Weibulls wants to - focus on total cost,

- Think freely, we have a lot of latitude in the beginning,
- Create short cycle times
- Be the technology leader
- Systematize, modularize.

2. *Demo of a better rack prototype. With torpedo beams loaded and unloaded.* (This had to be restricted to just watching a rack in the cave due to my colleges at Prosolvia Clarus AB, who couldn't get their act together).

For the demonstration, we all stood up and walked over to the cave in the adjacent room. We had transformed the CAD model of the rack to VR-files and loaded them onto the computer controlling the cave, figure 5.4.

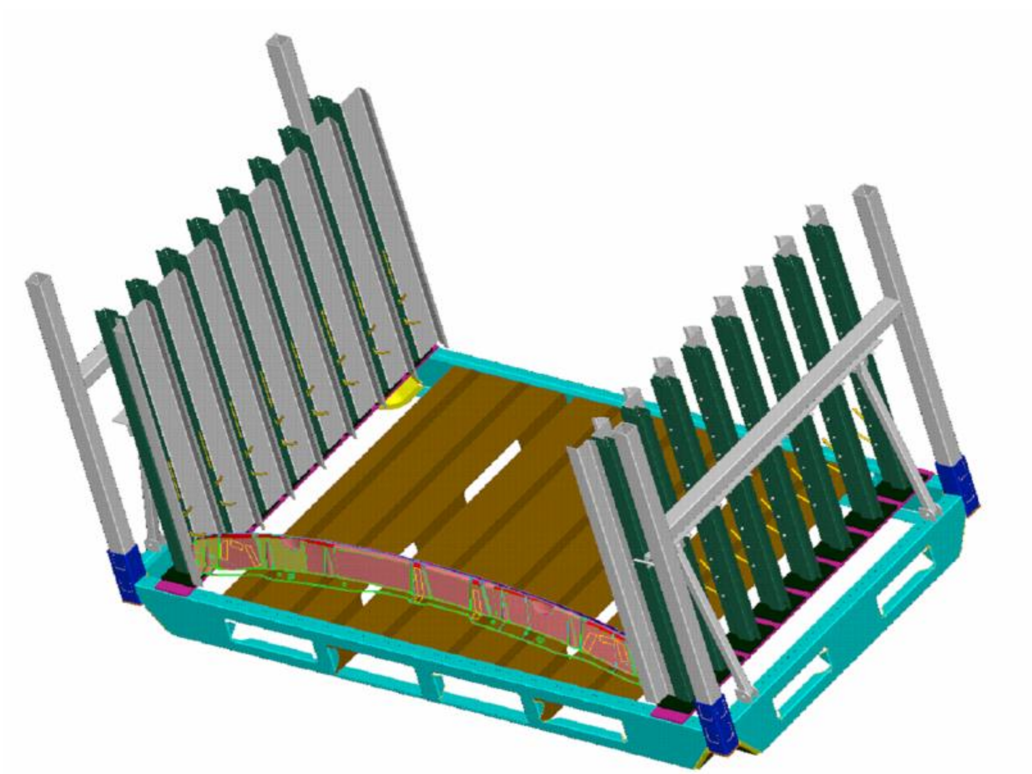

Figure 5.4. The Weibulls' torpedo beam rack with one torpedo beam in place

Wearing shutter glasses, our guests moved around the VR-model in the cave. I was in the cave with Alf Hansson, VOV, and told him to look inside one of the pillars. Doing so he could see what it looked like on the inside, then he was told to bend down and watch from below and was impressed by actually seeing what the rack looked like from that direction. I now asked Alf to step into the rack, and he (much to my amusement) treads air in an attempt to step up onto the rack. So complete was the illusion at that very moment. A moment later he said that *this was enough information for him to make a purchase decision on*. —Yes, Yes, Yes, I thought to myself, he has bought the idea and we have by-passed the clumsy prototype phase!!

3. *Demo of a better rack in a robot cell in a factory. (This had to be omitted this time due to the short time we had for preparations).*

Coming back from the cave, we positioned an overhead transparency with rack figures on the projector, figure 5.5.

Weibulls' Torpedo Beam Rack

Weibulls basic structure: SEK 1450

(Exclusive of electro zinc plating)

Pillars, etc (console pillars on one side and fixed on the other) inclusive of electro zinc plating SEK 11940 + structure SEK 1450 = 13 390 SEK

(Console pillars SEK 985 * 8 pieces)

Volvo basic structure ca SEK1950 - 2100

Weibulls structure: 90kg

Volvo basic structure: 130-140kg

Electro Zn plating costs ca SEK 350, for a complete rack, with transportation, a total of ca SEK 500

Hot dip Zn, ca SEK 600, inclusive of transport

Figure 5.5. Our offer for the torpedo beam rack

The numbers were taken note of, but no greater reaction. We pointed at the weight saving and they said yes, and that was that.

4. *Discussion of racks*

What Weibulls has done so far, basic measures, surface treatment, machines for rack production, LCC, etc. These issues were treated very superficially. They are better brought up in smaller groups elsewhere.

5. *Volvo's and Weibulls' roles*

There is an interest from Volvo of continuing these talks and cooperation for some additional steps.

6. *Console pillars*

   - *Patent situation*
   - *Actors: LBM, Tiegler*
   - *An own solution in Småland*
   - *Develop a Swedish solution. Help from Volvo?*

Our investigation of patents shows no preliminary objections to using the technology freely. Volvo can accept a "Småland solution" but will not say whether they will support such an action or not.

Alf Hansson: 1/ the reason for using console pillars is the precision and quality, 2/ attack the cost!

PO Möller: 1/ the lead-time is to long, today 8-10 weeks. This is far to long. Because there are often changes late in the project, 2/ collapsibility of a rack is important.

Jörgen Håkansson: two things wrong with console pillars: cost and lead-time.

7. *Next meeting*

Axel will set up a meeting on transponders46 as information carriers on racks.

Other meetings are decided as needed.

Other points that were brought up during the meeting were:

- Krister Andersson: how do we design the guide of the rack when using robot handling? This must not be forgotten.
- Transponder technology as an information carrier is interesting for logistics specialists Magnus Salander and PO Möller.
- Request for quotation from Krister Andersson, VOV, for two variants of torpedo beam rack. Number of racks to quote: 1 and 300 (obviously they want to see our economics of scale).
- Possibly we have gotten the wrong torpedo beam model from VOV.
- Discuss service in connection with logistics.

All Volvo packaging is returned except that coming from USA and Japan.

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[46] There was a sister company to Weibulls, a transponder specialist company, i2R ltd, in the Syneco group.

At the meeting Krister Andersson, VOV, had requested a quotation for the torpedo beam rack based on the Volvo structure. I forwarded the request to Weibulls' sales manager Bo Ahlberg.

Before going home that evening, I faxed minutes from today's meeting to Axel so he could read it first thing tomorrow.

5.3.10 Week 23: Winding down

The 16 hours written up on the project this week was spent "cleaning up", distributing additional information, archiving drawings and such. This first phase of the project was pretty much finished.

5.4. End of the first project phase

As can be seen from figure 5.6, depicting how I wrote up hours for this project (Prosolvia Research & Technology AB project number 3148), there is an intensive first phase covering weeks 14-23, then there is sporadic activity until week 44 when action picks up again until the end of the year.

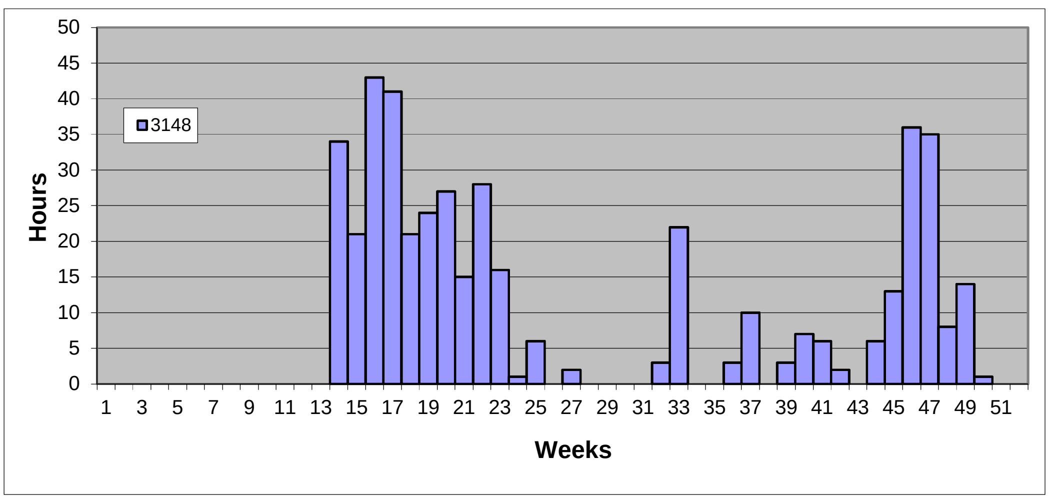

Figure 5.6. Hours used by the author on the Weibulls rack project (PRT internal designation 3148)

What happened was this. Volvo Car Corporation was redesigning part of their production facilities in Torslanda, Sweden, in what was called the "G-fabrik". Volvo Olofströmsverken, VOV, situated in Olofström, Sweden, was responsible for the logistics between the VOV stamping plant in Olofström and the Volvo Torslanda plant and now that had come to include logistics within the "G-fabrik" also. This involved the racks used and their status – whether they were within tolerance, etc.

It was necessary to check the racks for trueness, because Volvo Car, contrary to other automobile manufacturers, used “unintelligent” robots lacking tactile ability or a seek-and-find function. They just picked the goods where it was formally supposed to be. Therefore, it was important to keep all parts of the rack always within tolerance.

Racks risked becoming warped during forklift handling because the drivers drove like crazy and it seemed impossible to educate them. Better then to design racks accordingly and to check them for trueness regularly.

At VOV logistics people decided that all empty racks must be tried by truing devices prior to being returned to VOV for reuse. They realized that they had a need for seven such devises corresponding to seven different high-risk types of racks. Since Weibulls had stuck their neck out boosting about their ability as regards racks, VOV turned to them for help. Weibulls turned to PRT and the issue landed in my lap. This became PRT project number 3166 and it was a continuation or consequence of the previous rack project with PRT number 3148.

During essentially four-five summer weeks, the seven devices were designed by engineers working through what would normally have been their summer holiday. In parallel and afterwards a supplier to Weibulls made the truing jigs. Hours that I spent on this project are shown in figure 5.7.

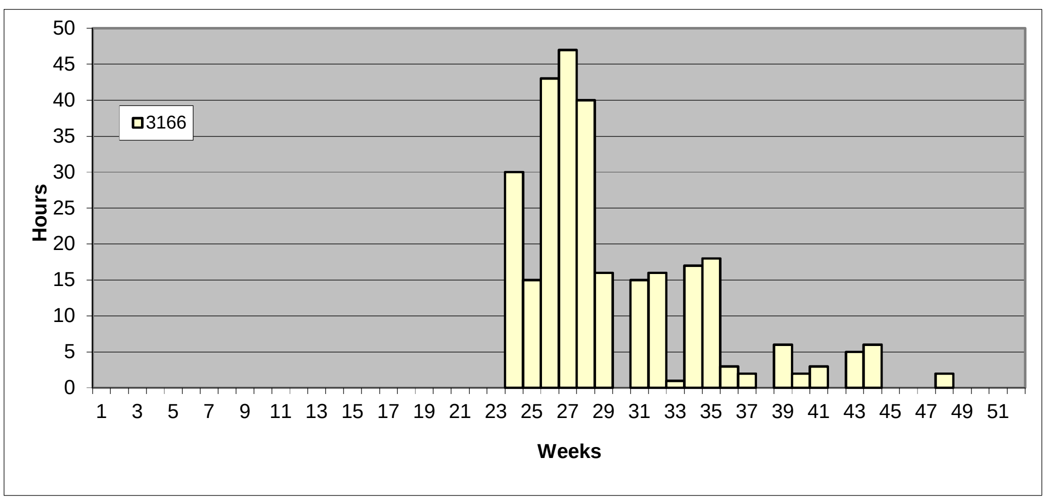

Figure 5.7. Hours spent on the Weibulls rack truing devise project by the author

The sporadic hours during the fall, figure 5.7, are “cleaning up” activities such as checking that things work as expected, attending meetings, fitting labels to the truing devices, answering questions, etc.

The 3166-project was interesting from two points of view: first it was offered to us because of our previous achievements in rack project 3148 and it was not something we could have anticipated or planned from the start, and second it was played at the edge of good conduct from my side but ended well.

Mr. Alf Hansson at VOV had indicated that they were in a hurry and needed quick action. To be sure, that we would get the order I presented VOV with a time plan that was too optimistic and that would not hold. However, I thought that if everything worked out as expected the delay would be "acceptable". As a project leader, you have no formal authority outside of your project, so when the line organization was incapable of supplying me with the design engineers that I needed all I could do was to accept the situation. That soon resulted in my project being formally very much behind schedule, which resulted in some very angry reactions, but then VOV was already on the hook so to say, and besides I had learned that the "G-fabrik"-project was a bit late so hopefully the consequence would be small if any.

As expected, the 3166-project landed well so everybody was happy. PRT made a gross profit of 57% and since lots of engineers had been involved this was one of the most profitable projects ever for my employer.

5.4.1 Rack project 3148A

In an effort to win a rack competition, we started project 3148A. Figure 5.8 shows my involvement. This was a very special high paced effort to concept develop and detail design a novel rack for front side windows.

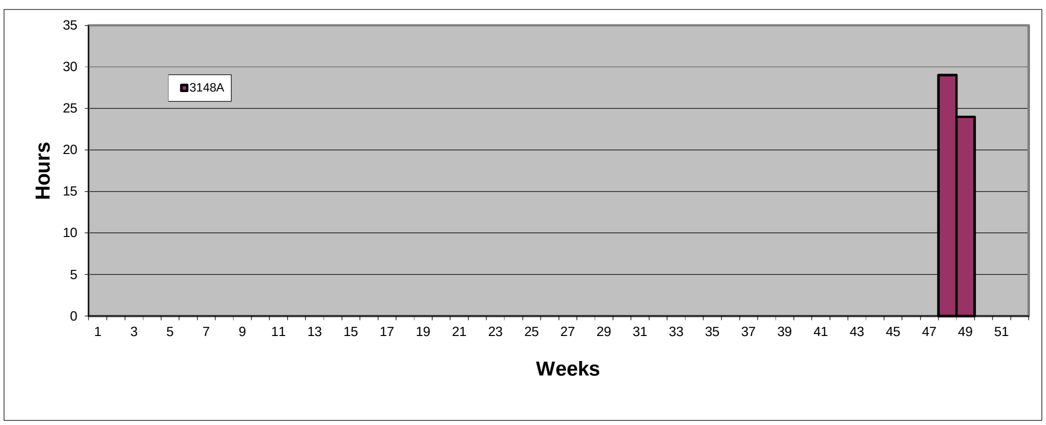

Figure 5.8. Hours spent by the author on PRT project 3148A for its customer Weibulls

In talks, that I had with Mr. Lars R Johansson I had asked him what Weibulls could do to win an order for racks and then he had told me that Volvo Car Corporation (VCC) had just invited suppliers to present solutions for racks that should carry front and rear side windows. It was to be a new rack design and ergonomic aspects were important. I asked if Weibulls cold participate in this competition. He said yes and therefore I contacted Axel Leijonhufvud and sold him the idea that by taking part in a competition between the present suppliers and presenting the very best solution, Weibulls would be chosen by VCC as a tier one supplier of racks.

Unfortunately, we entered the competition after it had started, which gave us only two weeks for concept and detail design. The very narrow time frame necessitated the fastest possible way of working. I was lucky to have onboard an engineer that had started out in production, was creative, and could sketch in Catia just as fast as anyone could by hand, so the creation of CAD models was no problem in itself. The problem was the creation of a superior concept and that of dimensioning.

Racks are very roughly handled. They are loaded by forklifts on and of trucks and train wagons, and when transported inside the factories. The drivers are careless and often run into the racks at high speed missing the entrance for the fork and therefore every rack must be fitted with a "fork protection" in order to protect the goods carried by the rack. We could have just copied the present design, or just guessed at dimensions, but that would not have put us above the competition so we analyzed the problem in order to come up with something better.

The design engineers and mechanical analysts of PRT were organized in two different departments and very rarely did they cooperate. Now we needed to do just that, and fast!

For the dimensioning I did not need very precise numbers, an estimate within 20-30% was just fine, but speed was essential. This was contrary to the culture of the mechanical analysis department so it did take a day or two to bring the message across. At last the head of the department became interested and we cooperated very fruitfully.

We created two models, figure 5.9. With the Virtual Model software the *maximum force* acting on the rack could be calculated for the given masses, speed, and elastic properties (spring rate). With FEA and the given geometry and maximum force, the mechanical stress field and *spring rate* could be estimated. The coupling between the two models and respective analysis were the fork-protection spring rate and maximum fork contact force. We allowed plastic flow but said that there should be no visible remaining deformation.

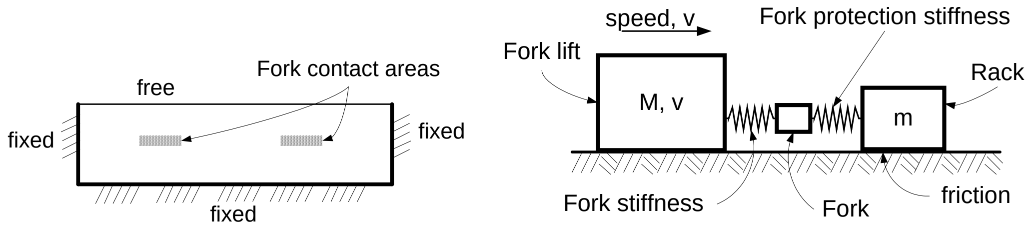

Figure 5.9. The "fork protection" is very simply modeled for a quick FEA analysis. The forklift and rack collision was analyzed by aid of the Virtual model software

By switching quickly between the two modes of analysis and not exaggerating the demand for precision we very quickly came to a satisfactory design that was both lighter (lower mass) and cheaper than the traditional design, although we had used ultra high strength steel. We would later use this as a proof of our greater competence compared to that of Weibulls' competitors.

This way of working, which is exactly how a skilled design engineer who is proficient in strength of materials and mechanics works "within himself" so to speak, was a very first for PRT. We nicknamed this way of using fast numerical estimates for "quick shots" ("snabba skott" in Swedish). The fun and efficiency of this cooperation lingered in my subconscious mind for some time afterwards and was the direct cause for the creation of a new business process called COD, calculation on demand.

We were told that we came in second in the competition. Allegedly, because the winner had a somewhat simpler design where one part was removed from the rack during loading and unloading of windows, something we had got the impression was not allowed, because of the risk of the piece getting lost. Perhaps their explanation was true, or perhaps we lost due to politics beyond our control.

5.4.2 Total rack project activities

My activities in all projects that Prosolvia Research & Technology undertook for its customer Weibulls during 1998 are shown in figure 5.10. Activities continued at a low level during the following year but are not shown here.

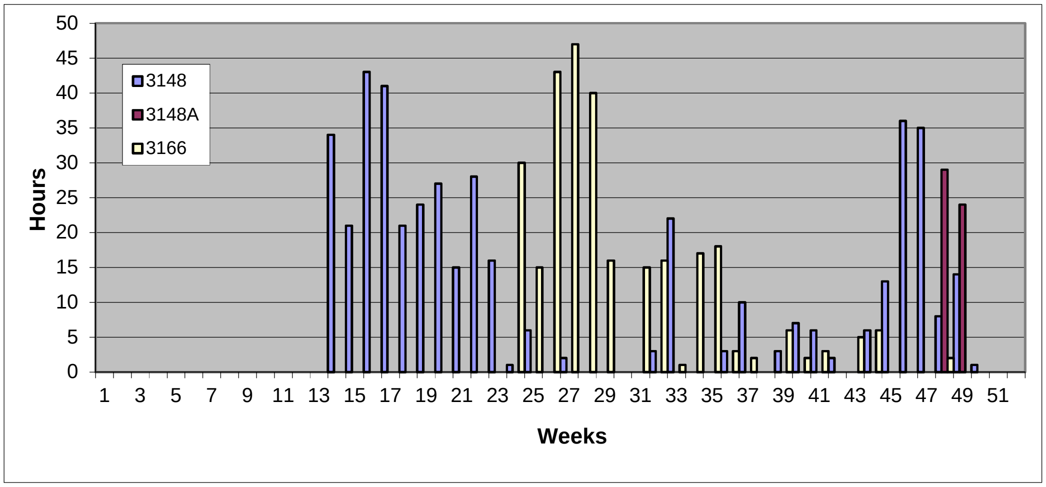

Figure 5.10. Hours spent by the author on all PRT projects for its customer Weibulls during 1998

5.4.3 End note to Case 1

An analysis and discussion of this case is given in chapter 7.

6. Case 2 – Calculation On Demand, COD

For the same reason as in Case 1, a narrative style is used, where "the author" in the following case description becomes "I".

6.1. Introduction

In between the previously described Case 1 and the present Case 2, the mother company Prosolvia AB went bankrupt and the healthy daughter company Prosolvia Research & Technology AB (PRT) was acquired by Frontec AB and renamed Frontec Research & Technology AB (FRT). Business in FRT went on as before in PRT.

6.2. Background

The origin of the project described in this case was two factors.

The first factor was my experiences from project 3148A described in chapter 5.4.1. In that project I did not need very precise numbers for dimensioning, but speed was essential. This was contrary to the culture of the mechanical analysis department where mechanical analysts took pride in delivering answers with as many significant digits as possible, regardless it seemed, of the time used.

However, by switching quickly between two modes of analysis and not exaggerating the demand for precision we very quickly came to a satisfactory design. This way of working, which is exactly how a skilled design engineer who is proficient in strength of materials and mechanics works "within himself" so to speak, was a very first for our company. We nicknamed this way of using fast numerical estimates "snabba skott", which is Swedish for "quick shots".

The second factor was my opinion of there being a poor fit between how work was done and customer need. The mechanical analysis department of Frontec Research & Technology AB would quote on jobs offered. If the quotation was accepted, FRT would start an analysis cycle of modeling, creating a mesh, run the analysis, post process the results, write a report of substantial thickness and then finally report the conclusions to the customer while at the same time handing over the report.

Normally since FRT was a consultancy company, there was only a 70-75% utilization of resources, so often times there was no new assignment waiting for the analyst as he was finishing his first assignment. This had the effect that the analysts kept refining results fiddling with this and that (often to learn more, but also out of curiosity) to fill out their time "because there was no new project waiting so their time was gratis".

As a company internal customer to the mechanical analysis department I found their "one size fits all" kind of working unsatisfactory, to say the least. I wanted a more agile response more in tune with my need as a customer. I wanted them to understand the standing of their analysis results in the grander scale of the project as a whole. I wanted them to understand why the design engineer wanted the analysis done and how the results are used. That the mechanical analysts often did not have a clue as to the practical value and the raison d'être of their work was apparent from for instance reading the "recommendations" they often lavishly gave in their reports.

Usually my needs were simple. In projects that I managed, there occasionally would surface a need for a FEA or CFD analysis. I then placed a small mechanical analysis job of about one or two weeks on the mechanical analysis department.

Before the contact with the analyst I would have spent one day selling, quoting, negotiating, getting accept for the order and discussed what to do, and when and what to present, etc, with the customer. To this should be added the day that I would have to spend explaining the results to our customer and subsequently close the project and archive project documents. Therefore, two days were in effect already spent as the analyst was given the job. The analyst wishing to do what he thought was a good job would ask "how much time do I have" and answer that question himself by diving the total amount of the order with his formal hourly rate and come up with a figure that was to large for our business to be profitable. It seemed impossible to change this way of reasoning. The culture of the mechanical analysis department was way to strong for that.

At this point in time, at the turn of the millennium, industry was turning more and more towards mechanical analysis and simulation not only as a tool for verifying design but also as an exploratory tool. This demanded higher speed with less administrative bureaucracy. I was very dissatisfied with the situation at hand. Then during that years Yule and New Year holiday, I had an idea.

6.3. Project execution

The heading "project starts" is not entirely correct since formally there was no project but my first ideas and hunches that would later lead to a project or rather, as will be seen, two or three projects or phases of a project, if you will. However, informally we can say that the project started in the first week of 1999.

6.3.1 Weeks 01- 04: Idea development

The idea was to use the Internet and a specially designed website to let customers define/describe their problems themselves and specify the problem by filling in a form on the website. Behind all this should be a database and furthermore *all non-*

value adding activities should be either removed or performed automatically. This would give us continuous local presence as described by the slogan: "Any time, anywhere".

Any time, anywhere was a consequence of using the Internet. A website is up and functioning 24/7. All that is needed is at least one operator on duty. However, this person could be anywhere on the globe as long as he had access to the Internet.

Continuous local presence meant that by visiting our website an icon should be downloaded and installed on the customer computer so that just by clicking this icon, the customers' web browser should be loaded and our website should come up. In this way, we would never be more than a mouse-click away.

All non-value adding activities are removed or performed automatically. This was the chance to make money where our competition could not. Speed is increased and cost is reduced to nil, almost.

This was a Skunk project at first. I used for several weeks an estimated 80% of my time advocating my ideas and trying to persuade people to accept this novel business method. Time used was written up on other accounts. Later, as the concept was accepted and launched as the largest financial undertaking ever by the company, this account was partly used for financing other projects.

In week four I assembled my thoughts on a new mechanical analysis service in a document, see appendix 2. The arguments given in the document were used in the process of selling the idea internally in the company. I succeeded to sell the idea to Dr. Hans Bjarnehed, the manager of the mechanical analysis department because he had liked the "quick shot" exercise we had had in the autumn.

6.3.2 Weeks 05-07: More idea development

If one wants to have a machine perform work, the work must be very precisely defined. Here the idea was to have our customers define the work for us, and feed data into a database, so that we could manipulate data manually and automatically.

We called this form "blanketten", which is Swedish for "the form". To logically split up any possible work request in a logical form proved to be difficult. Hans B and I spent a considerable amount of time on this task over a period of two to three weeks. We used large pieces of cardboard, a whiteboard and different color felt-tipped pens. It was quite fun however, and we both felt that this was something new and potentially very valuable to the company (although it was still a Skunk project). As the work progressed additional forms or tables, beside "blanketten" were added as needed, such as "Shoppen", the shop (describing the content and structure of the website customer interface), "tolkning av kunddata", interpretation of customer data, "offert", quotation, etc.

I summed up our work in a document called "Snabba Skott, Ny Beräkningstjänst, en intern produktutveckling" or in English "Quick Shots, New Calculations Service, an internal product development". All through the project this document would be elaborated on and serve as documentation of the present state of the project and as an informant given out to sponsors and others with a vested interest in the project.

To give an idea of how data and the customer website interface was structured during the early phase of the project the form called "blanketten" as given in the first "Snabba Skott" document, is shown in appendix 3.

The process, later to be known as the COD-process, figure 6.1, was virtually unchanged during the project. A confirmative telephone call from the so-called COD-pilot to the customer at the very start and finish was added later. As the project progressed, we came to take advantage of the fact that all employees used mobile phones provided by FRT.

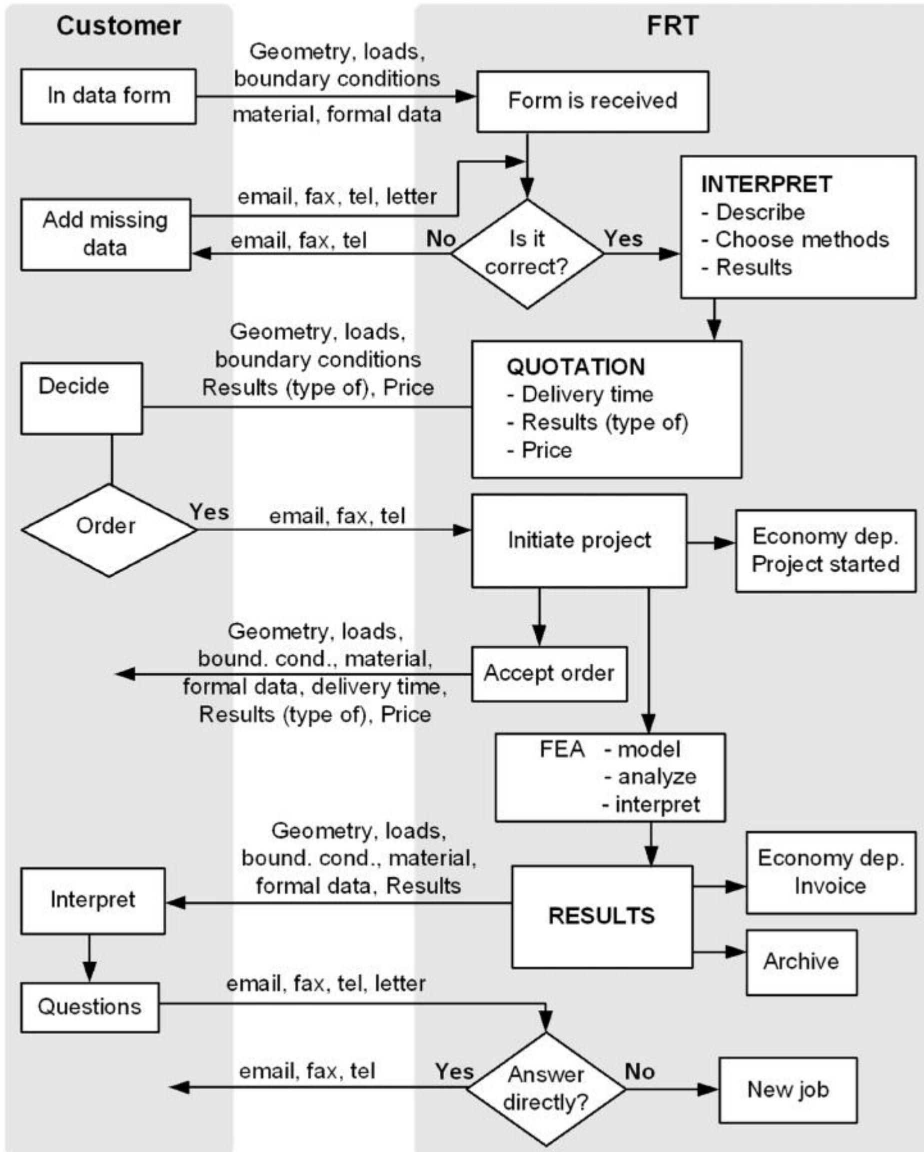

Figure 6.1. The COD process

As the customer filling in data for a request for quotation finalized his actions on the website by pressing the send button, a message (using sms, short message service) was automatically sent to the phone of the COD pilot on duty, telling who the customer was, his phone number, etc. When this happened the COD pilot should rush to his computer, log on to the COD website, check out the requests of the customer and then call the customer and inform him of actions planned or ask for missing or additional information.

We actually guarantied our customers a quotation within half an hour from the placement of their request.

6.3.3 Weeks 08-11: Convincing people

During these weeks, a tremendous effort was put in to convince people in the organization of the merits of the idea and to prepare for the upcoming board meeting where "Snabba Skott" was to be presented and grants for the development would be requested.

A problem was the CEO's total lack of understanding. He just seemed not to be able to "get it". He perceived the idea as some sort of call service, as a supplement to the business as usual activities of the mechanical analysis department. This was strange, I think, because everybody else seemed to grasp the idea without much effort.

6.3.4 Week 12: The board meeting

On the board of FRT were the vice president of our mother company Frontec (who was also the largest owner of Frontec), the Frontec vice president for sales, president of FRT and employee representatives. I had prepared a presentation and written a report, see Appendix 4 that clearly explained the "Snabba skott"-idea and gave the arguments that Hans Bjarnehed, head of the mechanical analysis department and myself had so far come up with. Included was also a budget and timeline for the project that I sought acceptance for.

When it was time for my presentation, I started by pointing out that what we, Hans and I, were suggesting was a new service that would yield

- Increased turnover
- Increased profit by allowing a higher hourly rate
- New customers
- Improved service to present customers
- Faster invoice handling
- Less administration

A substantial advantage compared to competitors since we will be the only actors in a new filed.

They were each given a copy of the 18-page report; I positioned a slide on the overhead projector, and pointed out that the present way of handling short mechanical analysis jobs is inefficient indeed, figure 6.2.

A five-day mechanical analysis assignment is offered for a fixed price of 30 000 SEK. But in reality there is always a workday before and after the assignment for quotation work, communication with the client and archiving. The actual time worked is therefore closer to seven days. The revenue per day is 30 000/7 = 4 333 SEK/day.

	1	2		3	4	5	
O/C Offer & communi-cate	**M** Create model	**M**	**A** Ana lyze	**P** Post-proc-ess	**R** Report	**R**	**C/Arch** Com. & archive

Figure 6.2. The old, traditional way of working

A five-day mechanical analysis assignment is offered for a fixed price of 30 000 SEK. But in reality there is always a workday before and after the assignment for quotation work, communication with the client and archiving. The actual time worked is therefore closer to seven days. The revenue per day is 30 000/7 = 4 333 SEK/day.

The new “Snabba skott” method, figure 6.3, comprises only three days and costs 20 000-30 000 SEK as a fixed price assignment. The revenue per day is from 20 000/ 3 = 6 667 SEK up to 30 000/3 = 10 000 SEK.

By this new method, it would be possible to lower the cost for the customer, increase company earnings (the number of hours worked is not declared) and reduce delivery time. This method is applicable to all mechanical analysis assignments, but the profit will be the greatest for short jobs. I further tantalized them by presenting as facts a rough estimate of market size, figure 6.4. This was a wild guess of course. Nobody knew the size of the 0.1-1 week market.

1		2		3	
IO	**M**	**M**	**A**	**A**	**P** **R**

Figure 6.3. New, web-based work method. Legend: I = Interpret

Now that I had shown them what they could get I presented my request for money to run the development project. It consisted very simply of two parts: work and investment.

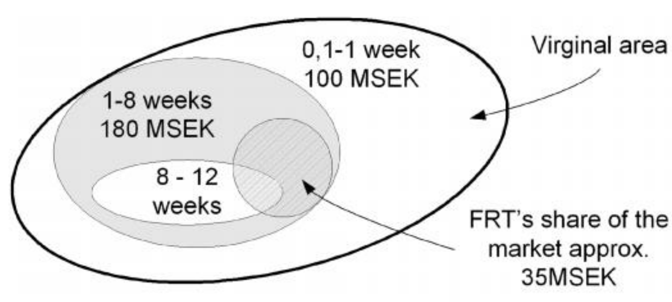

Figure 6.4. A rough estimate of market size presented to the board of FRT

Work is based on time used, which is calculated from 40h/week and 600 SEK/h.

Project management (20h/week)	18,0 weeks	216 000 SEK

Skylten (the "display window")	2,0 weeks	48 000 SEK
Shoppen (the shop)	1,4 weeks	33 600 SEK
Work method	6,8 weeks	163 200 SEK
Work through one case	2,4 weeks	57 600 SEK
Website (programming of)	7,0 weeks	168 000 SEK
Market introduction	10,0 weeks	240 000 SEK
Sum total	**29,6 weeks**	**926 400 SEK**

Investment: Telephone line, modem, PC, fax program, Office program, scanner, digitizer tablet, mouse pen = 30 000 SEK

Total Cost 926 400 + 30 000 ≈ 960 000 SEK

The board members were also shown a timeline for the project created with Microsoft Project software printed out in color, figure 6.5.

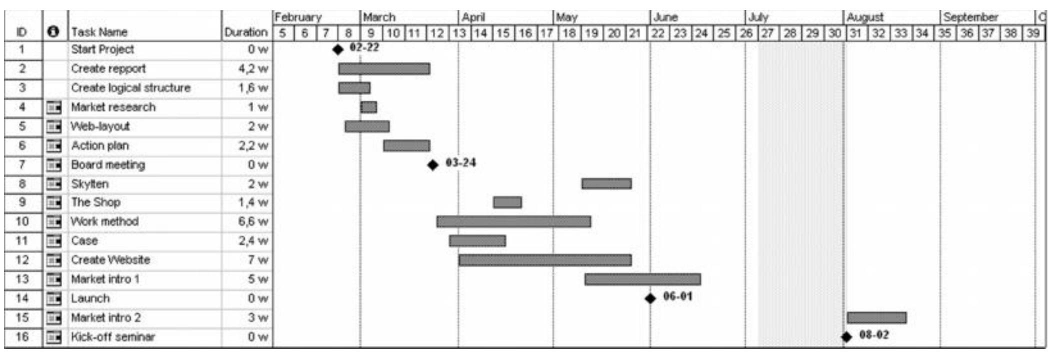

Figure 6.5. The "Snabba skott" timeline presented to the board as bases for a request for spending of 1 million SEK

The vice president of Frontec (also its largest owner) said, "Add half a million to that and I'll believe in your plan", and then he added, "OK, go ahead with your project".

6.3.5 Weeks 13-14: Inviting the first two project members

I had come away from the board meeting with the clear impression that I had an OK to start the project. However, I had other projects to tend to so not very much was done, except inviting mechanical analyst Marcus Wallentin to take part in the project, and continue the refinement of the inner structure of "Snabba skott".

Marcus became the first project member and started by looking into what had been done so far from an operative's point of view.

I had selected Marcus on recommendation from his manager Hans Bjarnehed. Further, Johan Berg was invited because he was thought to be a suitable project member because of his personality, expertise in mechanical analysis and knowledge of HTML programming. We intended to gather additional project members, such as programmers, from our office in Jönköping and maybe someone from Stockholm.

6.3.6 Week 15: Summing up resources

We needed HTML- and database competence. I fished around for a name. We had a software engineering department with people who had contributed code to Linux, helped develop the wavelet technique and more. They were very bright people indeed. From them a name came up on several occasions. It was Joel from our old sister company Interactive.

Interactive AB was a company that had been a part of the Prosolvia group, just as FRT, but had set out on their own and changed name to Insite AB. Therefore, it was like staying in the family when I contacted Maria B, project manager from Interactive for help with creating the website and database.

We met. Maria signed the non-disclosure agreement, was given a description of the project, and was asked for a quotation. She was told that we wanted Joel for the job. I also knew, but she didn't know that I knew, that they were short on jobs, so probably I could squeeze them to give a low price quotation.

The project dearly needed support with marketing so therefore I met with Zeth M, a nestor of the Gothenburg world of advertising and commercial positioning. I asked for ideas on marketing and was given a host of them. We sketched market activities on a timeline drawn on a large piece of cardboard. When I asked what a probable cost would be, it was twice the amount I had presented at the board meeting three weeks before. I felt happy that I had been given 50% more money than I had asked for. Zeth was invited to participate together with his network of contacts on a fixed price bases.

This week the project really started as Marcus W and Johan B began to look into the documents that Hans B and I had created so far.

There were things like data communication that we so far had neglected. It is interesting today to see what we thought then. The following is from a document written at the time.

Data Communication Snabba Skott

Foremost CAD files can come to us in many different ways. Therefore, "Snabba Skott" must be able to handle many different sorts of data media, like

- Zip diskettes
- 120 MB diskettes
- CD-R
- CD-RW
- PCCard disk memories
- Magneto-optic discs
- 8mm DAT tape

> Most interesting probably is 120 MB diskettes since these can be read and written directly in a users computer. The diskette is much easier and faster to handle than is the CD-X variant.
>
> DAT tape is large company standard but poorly suited for transportation in a paper envelope. Here the CD-X and 120 MB diskette have an advantage.
>
> PCCard disk memories are most common with portable computers.

Now that Marcus and Johan were participating, it was important to impose my way of running a project, which is based on maneuver thinking and dynamic product development. I therefore issued a document saying:

> **Regarding the project**
>
> **Timebox:** time of delivery is locked, but the content can be adjusted, that is: functionality can be postponed.
>
> **Front-end-loaded:** all activities must start immediately. Start forcefully and eventually reduce intensity later.
>
> It is all about: as fast as possible have something functional. Test in parallel with development.
>
> Incremental development, that is: according to the above plus openness towards future widening of scope.
>
> As fast as possible – test the system!

At this time also new editions of the action plan, ”blanketten” (the data structure form) and a description of the process were issued as a description of project status.

6.3.7 Week 16: Asking for money

While Marcus and Johan were picking up speed working with structure and interface issues, I had meetings and telephone calls with Maria B of Insite AB regarding their quotation for web and database programming.

Insite was a consultants company and so were we. We both knew all the tricks of the trade. I could not give a definite description of the job to be done since we were just at the start of the development of something new and no one knew exactly where we would end, so they tried so safeguard themselves in any possible way. We seemed to get nowhere at all. There was a lack of trust, maybe.

The chairman of FRT and his board had approved the project, but still Lars S, the managing director was hesitant. He did not understand the vision I had presented and since his background was mechanical analysis I was sure he did not understand marketing. Therefore, I arranged a meeting between Lars S, Zeth M, a self-employed marketing specialist and myself with the following objectives: create mutual trust between Lars S and Zeth M, prepare Lars S for the high cost of marketing, and have Lars S feel that he was on top of things.

I also had a meeting with Lars S and Per S, the design department manager about the project just so that Per S felt involved and informed. Just to smooth things I presented a budget, see appendix 5.

Notice how nicely the total sum for the project lands just below the 1460000 SEK granted for the project by the company board.

I also presented a timeline for the project, figure 6.6. Please not that a number of project meetings are scheduled to take place every Friday afternoon at 15:30.

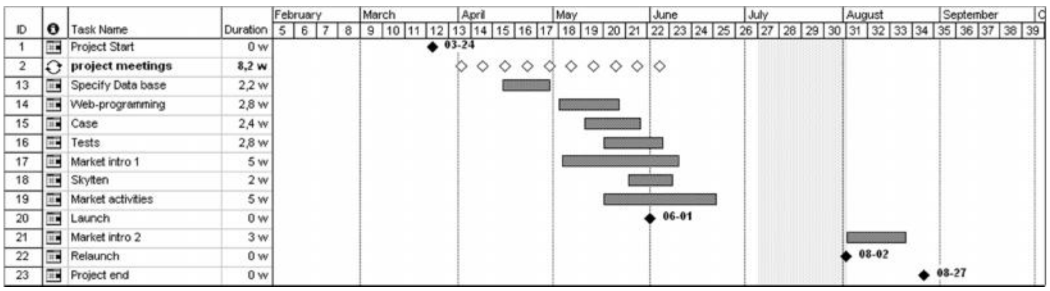

Figure 6.6. The project timeline as of week 16

6.3.8 Week 17: Business as usual

The project continues with the two analysts working about halftime. I had a new meeting with Lars S and Zeth about marketing and marketing cost. Lars S seemed to be satisfied with what he learnt about our plans for the project. However, I still had no clear decision to go ahead from Lars S. The board wanted me to run the project and I wanted to run the project, but my boss the president of FRT was obstructive.

6.3.9 Week 18: The turning point

I had a meeting with Maria and Joel from Insite AB. Maybe we could start with a small pre-study, just to get to know each other, for that would be a nice way for Interactive to learn more about the project and what we are aiming for. We decided on a small project worth 60 000 SEK as a start and a way to build trust between us.

I met with Hans Bjarnehed and we decided to modify the process. A telephone call from the analyst to the customer was added to the process, at the very beginning and at the end of the process. The idea was that a customer should have an immediate response so that he knows that we are tending to his needs. It was felt that this is necessary when you actually are communicating with a computer as is the case with a website. The telephone call at the end of the process is there mostly for to give the customer an opportunity to speak his mind, but also for us to get valuable feedback.

We also talked about potential benefits from using “Snabba Skott” and indulged ourselves in some statistics that I had just got from Anna-Maria K, our manager of finance, regarding fixed price projects at the mechanical analysis department.

A meeting with Lars S, the company president, was scheduled for the end of the week and I was preparing arguments to use at the meeting by writing yet another document, this time called “profitability analysis”.

6.3.10 Meeting with Lars S, the FRT president

My aim was to “sell him” the project idea and have him release the money I needed for the “Snabba Skott” project. I handed over the “profitability analysis” document that I had prepared for this meeting and I argued along the lines drawn up in the document. These are given in appendix 6.

First, a few caveat: A profitability analysis is extremely difficult to perform since this is a completely new product that does not yet exist on the market. One can take the stand that it is impossible to prognosticate our sales, for example for the first two quarters. Internet business as such can be very profitable, however.

6.3.10.1 Market Research

A simple market research had been made by phone. Customers were asked what they thought about ”Snabba Skott” after a short description of the idea. See appendix 7 for details. Conclusions were that ”Snabba Skott” was attractive to small and medium companies mainly. The large companies’ purchasers were not that interested yet. This might be due to the fact that if used, “Snabba Skott” would bypass them to some extent and their reluctance could be a sign of them safeguarding their jobs.

The design mangers of the large companies would get a new potent tool at a reasonable cost. Would they be interested? We did not know for sure, but thought that that would be the case.

Since I knew that Lars S was an analytical person who did not trust his gut feeling, or rather, his gut feeling cried stop because he did not like to trust intuition I had saved my strongest argument until last.

6.3.10.2 Five quarters of FRT statistics

I had asked Anna-Maria, our finance manager for financial details of fixed price jobs with the mechanical analysis department and she had willingly given me an Excel file with data for the last five quarters containing 144 consecutive fixed price projects.

I sorted the list from the smallest to the largest job. The amount invoiced corresponded to calendar time spent as long as only one mechanical analyst was involved, which was the case for smaller jobs. So if the invoice was for 30 000 SEK that should correspond to roughly one to one and a half weeks of job, and 60 000 SEK to three weeks, and so on. Further, a little analysis reveals that the first 80% (number 1-115) of the jobs yield 26% of the turnover, figure 6.7.

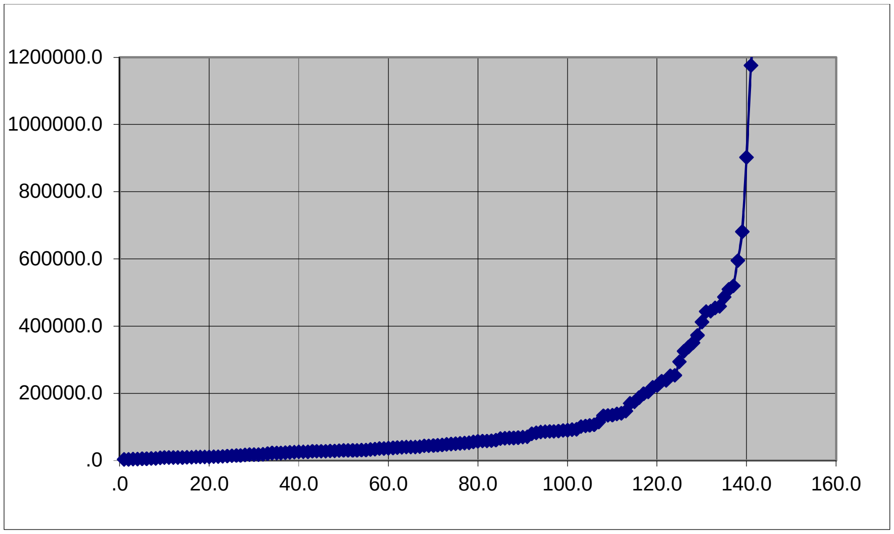

Figure 6.7. Invoiced amount in SEK vs. projects ordinal number (sorted) for five consecutive quarters of fixed price jobs at the mechanical analysis department

We can see from figure 6.7 that there are many small jobs and a few very large ones. The curve looks like a hyperbole. This is what one would expect. To increase clarity, the same data, but with the largest jobs removed are shown in figure 6.8.

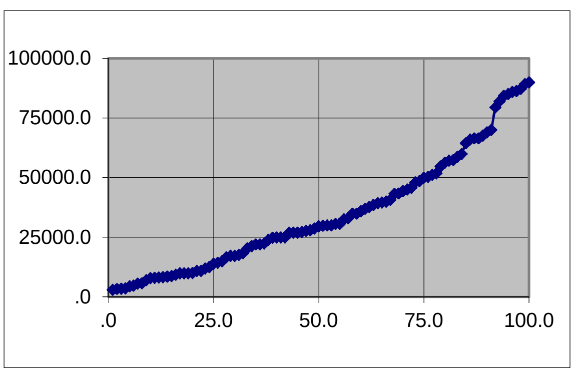

Figure 6.8. The same information as in figure 6.7, except truncated at 250 000 SEK to enhance clarity

Yet again, there is nothing exceptional to that. The interesting information appears when we create a *graph showing cost (money spent on the project) divided by invoiced amount* for the same sorted list of 144 jobs.

This should be *a number less than unity* for each project. Otherwise, there is a loss. From figure 6.9, we can see that on some projects FRT spent as much as six times more than they invoiced. This clearly shows that FRT was loosing money here.

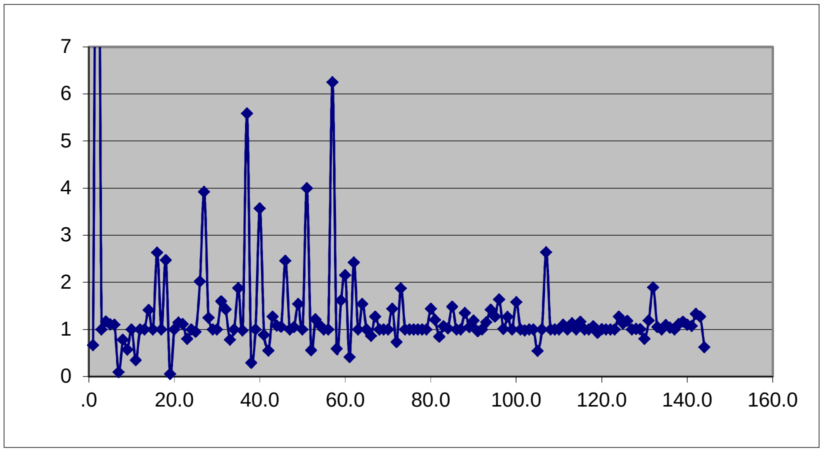

Figure 6.9. Project cost divided by invoiced amount vs. project ordinal number

It is apparent from the figure that the smaller jobs, the ones that take two, three weeks or less are more susceptible to overruns than the larger jobs. This is a very good argument for "Snabba Skott", since the aim was to increase control and remove much of the fuzzy start and termination of projects, which was just where much of the losses were created[47].

Further analysis revealed that the total cost for overruns was 3.4 MSEK. For one week projects it was 515 000 SEK and for two week projects it was 430 000 SEK.

This cost for lack of quality was in the same order as the profit of the company. Coming to terms with the overruns would almost double the annual profit. And finally Lars S succumbed and said: "OK, start your project".

At last, I was allowed to do what I had been doing for the past four month. The Skunk project had gradually become grey and was now white.

6.3.11 Weeks 19-21: A new CEO

There were more meetings with Insite AB. We discussed the project content and their quotation for the job.

Insite AB had a standard paragraph saying that they owned all code that they wrote. This was unacceptable to us of course. If I had not protested that would have meant that Insite could sell an exact copy of our website to anyone, one our competitors for instance.

Behind the paragraph lay a wish from them to be able to reuse code that they had written. The problem was solved by an agreement that we owned the code but they were allowed to use it as they pleased as long as it did not hurt the business of FRT.

Zeth and I had a few meetings regarding marketing and eventual give-a-ways.

[47] See section 6.3.4 Week 12: The board meeting, and appendix 4 – "Snabba Skott".

I had a new meeting with Lars S in week 20. He withdrew his approval of the project. Somehow, he had got cold feet. He did not forbid me from running the project so I continued as usual, prepared for another round of arguments.

After the Whitsun-holiday, we had a new CEO. His name was Hans-Åke Sundberg and he had been head of the office in Jönköping.

The change of CEO was probably a contributing reason for Lars S apprehension, I thought. Lars S probably did not want to commit such a large sum of money just before leaving his post. Lars S was transferred to Frontec, upwards and to the side.

I arranged a meeting between Hans-Åke our new CEO, Hans B and myself. After repeating the same arguments that I had used on Lars S, Hans-Åke agreed to the idea being good, but it was a lot of money and a big decision for him to make, etc. He liked the idea, but was a little apprehensive. Time would work in favor of the project.

6.3.12 Week 22: The race begins

Hans-Åke came around and gave the project his blessing; I was free to use the money I needed. This meant I could close the deal with Insite and at last have Joel onboard. It was time to formally staff the project.

I put Zeth in charge of marketing and everything concerning such matters. In his group he had Inger Alvelid, an art director with exquisite taste, and Charlotte Stengafvel who usually worked as coordinator in advertising projects.

Formally, Maria B from Insite was in charge of creating software code. She had Joel from Insite AB, Anita from FRT Jönköping office, and Johan from FRT Göteborg on her team.

In charge of interface and workstation was Marcus with, Joel, Anita and Urban in his group. Urban came from the FRT office in Jönköping.

These were all the team members I needed, but of political reasons I staffed, a couple of days later, a support functions group with Monica and Tomas, figure 6.10.

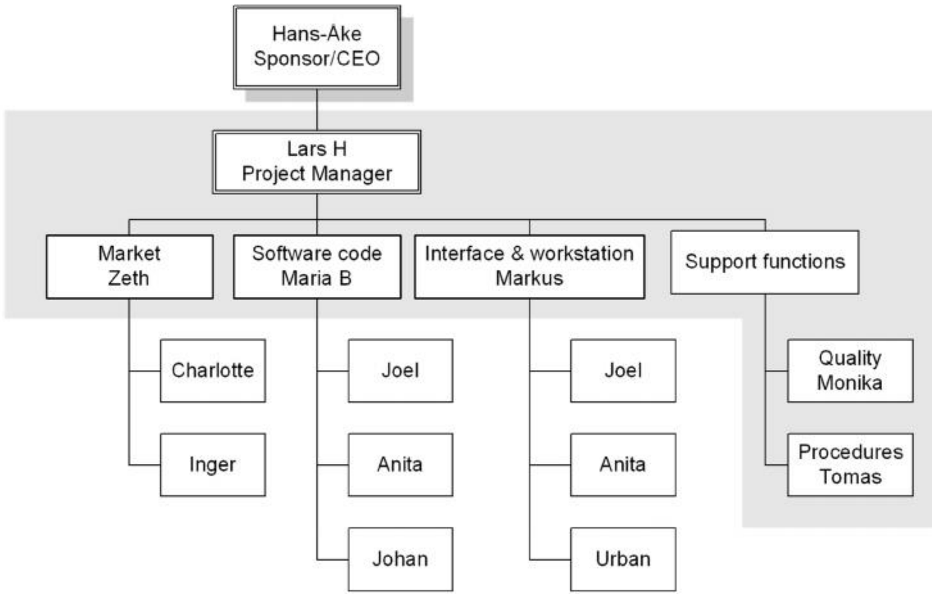

Figure 6.10. The COD project organization.

Monica was our quality manager and I thought that by bringing her on the team I could neutralize attacks for not following company prescribed procedures. The reason for having Tomas was the same. Tomas was well trained in the project management paradigm that says *plan the work and work the plan*, which was the absolute opposite to what I intended. However, Tomas was also an expert of Props, which is a stage-gate project structure developed at telecommunications company Ericsson (Props 1997) and licensed to Frontec, our mother company. There was a strong pressure to adopt Props and it was politically correct to say that you liked Props, although all it did was to put a straight jacket on a project and demand the production of a vast amount of unnecessary documents.

By this time, after much agony, we had decided to call the project COD, calculation on demand, as this was the name from now on for the service on the Internet we were to provide.

This phase of the project was started by taking Zeth, Charlotte, Inger, Maria, Joel, Anita, Johan, Marcus and Urban out for lunch. A long and good lunch. I do not like so-called kick-offs; they are just such a waste of time and money (Smith and Reinertsen 1995). In my opinion, it is much better to spend that money on a number of nice lunches.

The newcomers were given the latest documents, access to the project areas on the server, etc. Documents were also distributed to the mangers that should be informed.

6.3.13 Weeks 23-24: Setting the stage

I gathered the team Thursday morning 1999-06-10 at 10:00 and laid out my plan. By now all earlier timelines were hopelessly outmoded so a simple table would suffice.

I first gave a description of the background to the project and all benefits we saw from adopting COD. Then the timeframe was given: *the project runs from 10th of June until October30. Important dates are the first of September and the Technology Fair in Älvsjö, Stockholm, 23-28th of October.*

The goal of the project was formulated: *to create an Internet based mechanical analysis service called COD. COD must be fully functional and launched September 1 and thereafter presented on the Technology Fair in Älvsjö in Stockholm, 23-28th of October.*

Sub goals were set as follows:

1. Work method frozen and database described.
2. Web pages and database coded.
3. One case worked through.
4. User tests carried out.
5. Launch and company internal information meeting.

Presentation at the Technology Fair in Älvsjö 23-28th of October 1999.

Next was given a description (omitted here) of objectives and aim of COD, and all benefits to customers and FRT by using COD.

Other points were areas of responsibility, communication and data structure, strategy and time plan, see appendix 8. In the document that was handed out there also were an action plan and a things-to-do list, a rough budget and the schematic description of the COD process.

I had spent the lion's share of the meeting describing as vividly as I could the goal of the project. I wanted to convey a picture of what the final state would be, as if COD was already up and running and they were shown the process and had the work described by its users.

Actually if the idea of how I liked to run this project should be described in three words only it would be:

- Vision
- Tempo
- Self-organization

This clearly was no "plan the work and work the plan" project. There were no gates. Instead, there was a continuous follow up and occasional pointing out direction. The idea was that if every one is informed of the goal, of why we do this, and carries a shared vivid picture of the end result, then that vision works like a compass guiding each team member for every moment of the day. Likewise, tempo means the right speed; not to slow (no slack) and not so fast as to leading to sloppy work execution. Finally, self-organization means that team members should use their judgment and seek and give help as needed by the work at hand.

We ended the meeting, left the conference room, and walked together over to what would now be the COD room for the coming weeks. I had set aside a room for the project members to work in. There were three bare walls where we could hang papers, plots, pictures, newspaper clippings, etc. The idea was that in that room one should be emerged in COD.

As the project toke off, plans had to be updated and work divided between us. This was done with simple lists, as shown below.

Anita: Software and tools, platform, logical structure, web functionality written up, in and out data, database (Access), design, programming, documentation, GUI, explaining text, help texts and examples, function, links to Nafems for example, user tests.

Joel: Systems demands, database ODBC, web server IIS, mail server, SAFileup (suitable in combination with asp), development environment (server/local), user levels (read and write rights),

Users: IE4, Netscape 4, or higher

Johan and Markus: purchase of server, installation of server (test environment), define areas of responsibility and work packages before and during actual service, web design, graphical style, encryption, own tests, MD test, customer test, demo of service, domain registration, protect help pages, kick-off.

Lars: practical work method.

Others: workstations, saving project data, on the web server?, buy Access, create pictures (gif, etc).

The need for give-a-ways was further discussed between Zeth and myself and an idea that seemed nice was to create a COD symbol and print that with the web address on the front of good quality t-shirts. Charlotte would handle this and Inger would do the design.

6.3.14 Weeks 25-26: Business as usual

The team members had quickly found each other and work went very well. They all had their different personalities thereby supplementing and enhancing each other's strength and talents. The very difference seemed to create the harmony in the team.

The procedure and Props expert however became very nervous when he understood how I intended to run the project. It was completely different from what he was accustomed to so he sneaked away and talked to Hans-Åke, our CEO. Luckily, Hans-Åke had confidence in my ability so nothing changed except the Props expert was relieved from his duties on the project, on his own request. (Later when the project was successfully finished, he came and gave me his congratulations, saying that he had never thought that we would ever succeed).

We ended the week, just before summer holiday by having a meeting between our sales/market manager and Zeth, Inger, Charlotte and me. That was a very frosty meeting. Somehow, he did not share our enthusiasm for COD. This really was an indication of trouble but I disregarded that at the time as him just being thick-headed.

6.3.15 Weeks 27-30: Summer holiday

During traditional summer-holiday periods there is very little activity in a consultants company because large customers such as the automotive industry are pretty much closed (redesigning assembly lines for new model cars, etc). The COD project was also on holiday during these weeks.

6.3.16 Weeks 31-35: Finishing COD

The project was running fast and efficient. Numerous problems were solved every day. Team members interacted spontaneously as needed.

As project leader, I did not instruct them or point out what to do, instead during and in-between meetings, they informed me of what they had done and what decisions had been taken. Only on a couple of occasions did I point out a slightly different direction to which the team immediately adjusted.

We decided on a symbol for COD, figure 6.11, which would be used on T-shirts, on the website, all forms, icon for the computer screen, and as bumper sticker.

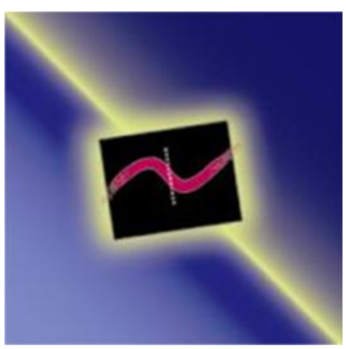

Figure 6.11. The COD symbol

During the short period of time that was the active programming (database and web pages) of the COD web site of about 300 web pages were created and two demo cases were created. A screen dump from such a demo case is shown in figure 6.12.

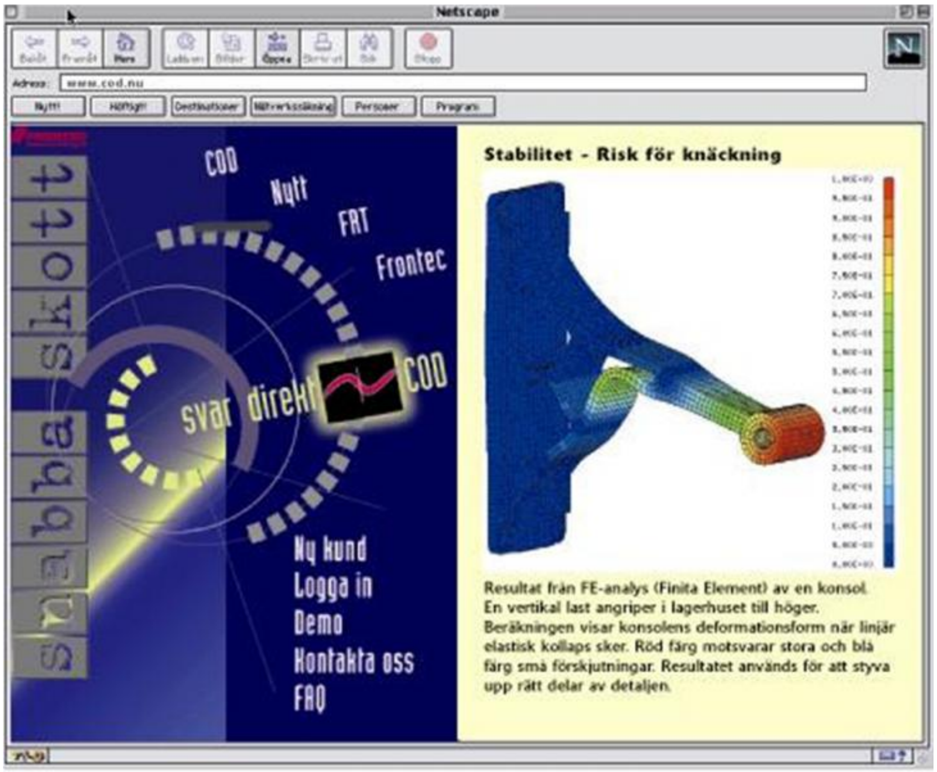

Figure 6.12. A screen dump from COD showing a demo case

During these weeks, we accepted trainees from another consultancy company that was giving a course in web design.

I had the trainees look into issues that we ourselves did not have time for, such as how best to arrange payment over the Internet.

6.3.17 Week 36: FRT celebrates the COD launch

Wednesday 1999-09-08 at 15:00 all employees walked across the parking lot from the FRT building to the IHM Business School building and their largest lecture hall. We were to celebrate the launch of COD.

Hans-Åke talked, telling us all how making the decision to start the COD project with its substantial cost had been the toughest decision he had made. Nevertheless, he thought that is was the right decision to make. Marcus informed his colleagues of COD from a COD pilots' point of view. He talked about how to use COD and its benefits. I also talked, telling every one how brilliantly the group had performed and what a great thing COD was.

After the briefing, we all walked back to the waiting celebration cakes decorated as COD symbols in our office. T-shirts with the COD symbol and web address printed on the front was given to each employee. Some T-shirts were saved for gifts to customers.

We all felt very pleased. The COD server was installed outside of the FRT firewall so all access to COD was via the Internet. This was done of security reasons. We did not want to risk that someone hacked into the FRT net through the COD website.

Now COD was up and running without any bugs as far as we could see.

6.3.18 Weeks 37-40: Every design engineer has COD in his rucksack

There was still work to be done on demo cases. Marcus and Johan toke care of that. In addition, there were help pages to be written and refined. Some additional analysts helped with testing and adding stuff to the FAQ pages.

During the COD project, we had proposed many advantages with COD. One that had come up was that every FRT design engineer should learn how to use the COD interface so that as he/she was sent out as a consultant design engineer he/she would carry in their rucksack a small mechanical analyst in the form of COD. This would be a "plus value" as we saw it and would in some cases give more value for money than did our competitors.

Anyway, every design engineer that had any spare time was put on the school bench and was trained in the use of COD. For this to work we had to write a short manual as a training aid. This of course was a brilliant opportunity for debugging the interface as engineers that were new to COD quickly found any inconsistencies.

6.3.19 Week 41: Press release

I had a meeting with Hans-Åke and Anna-Maria regarding COD. According to Anna-Maria, our finance manager, we had spent more money than planned from the beginning. And yes, if you included the training of design engineers and valued their time at market value we probably had spent as much as 2,5 MSEK instead of the 1,5 MSEK approved from the start. But training of design engineers was done in a self-study fashion in periods when they lacked customer assignments and the idea behind that was to give them valuable mechanical analysis ability that they could carry to customers and hopefully enlarge our business. This was not originally in the project plan but was added as an afterthought to the project and without providing any funds.

I wrote a press release and sent that together with printed material and diskettes with COD files and almost ready written articles to newspapers and journals that were targeting our market.

The press release is shown translated to English in appendix 9. Of course the Frontec publications: *Frontec Nytt* and *Frontec Magazine* that were targeting Frontec employees and customers respectively had articles on COD.

6.3.20 Week 42: The Technology Fair in Älvsjö

To market COD, I went to the Technology Fair in Älvsjö near Stockholm and stood in the Frontec booth together with our sales/market manager and a person from another Frontec subsidiary.

We found that 1999 was a poor year for the fair with very few visitors. In addition, even fewer seemed to find their way to our booth. At the counter, we had placed a large bowl filled with bonbons that was regularly visited by the few kids at the fair.

We had built up a small motion picture theater where we run a COD presentation by aid of a video projector and a laptop computer for a few potential customers. Overall, the whole thing felt pretty useless.

I gave an interview to *Verkstadstidningen*[48], a Swedish monthly journal on production technology and manufacturing that is read by circa 25000 production specialists and SME managers (Bergh1999).

6.3.21 Weeks 43-45: Direct marketing

To spread awareness of COD among our present customers and among what we judged to be potential customers, we produced a 4-page, 4-color leaflet in size A4, describing COD with text and pictures of COD and personnel, figure 6.13.

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[48] http://www.verkstadstidningen.com/,

C O D

Optimerad för modern produktutveckling

www.cod.nu

COD är hårt slimmad för att möta kraven från moderna organisationer med hög förändringstakt och korta ledtider. Våra kunder får precis när det behövs tillgång till den kompetens, som endast erfarna specialister med tillgång till marknadens mest avancerade program kan ge. Det betyder snabbare, mera precis produktutveckling - med alla de ekonomiska och marknadsmässiga fördelar detta innebär.

COD ur organisatoriskt perspektiv:

Specialskräddad för informationssamhällets allt plattare strukturer

När vi arbetade fram konceptet för COD, var det oerhört viktigt att vår nya tjänsteprodukt skulle bli ett uttryck för FRT:s ambition att bygga broar mellan forskning och verklighetsnära tillämpningar anpassade för moderna organisationer.

Lars Holmdahl, projektledare

Snabbhet, enkelhet och tillförlitlighet är nycklarna till informationssamhällets allt plattare strukturer. Genom COD kan alla inom projektet, oavsett nivå, direkt få svaren som löser propparna i utvecklingsarbetet.

Detta ger också möjlighet till ett iterativt arbetssätt med korta loopar, vilket är en av förutsättningarna för en lärande organisation.

Markus Wallentin, "driftsansvarig" för COD

COD ur konstruktörens perspektiv:

Med snabba, tillförlitliga svar löser vi propparna i utvecklingsprocessen

COD är strikt skapad ur konstruktörens, produktutvecklarens perspektiv.

Tack vare COD finns avancerad beräkningskapacitet alltid tillgänglig, via webben, för alla slag av mekaniska analyser, från enklaste överslagsberäkning till simulering av helbilskrockar eller tvåfasströmning. För närvarande är COD begränsad till linjära problem inom statik och dynamik samt termiska problem.

Om du tycker att COD inte täcker ditt problemområde, kontakta oss ändå, via telefon, fax eller e-mail. Gemensamt löser vi problemen.

I COD använder vi främst Finita Element Metoden (FEM). Typiska problem är risk för plasticering, utmattning, buckling och knäckning, beräkning av egenfrekvenser, modellering av frekvensresponsen eller beräkning av temperaturfältet vid olika laster.

Svaret skall täcka frågan, varken mer eller mindre. Därför tog vi bort eller minskade allt onödigt (= som inte adderar värde). Upplevs svaret någon gång som väl koncist, justeras detta lätt genom tilläggstjänster av olika slag.

Framgångsrik produktutveckling är i mycket resultatet av ett samspel människor emellan. COD-piloten (den som utför beräkningsuppdragen) får därför en central betydelse. Det är han som tolkar och modellerar (förenklar till rätt nivå) problemet, samt förhandlar om pris och leveranstid. Som COD-pilot kan jag intyga att det är ett fascinerande och spännande jobb!

Per Ekholm, marknadschef

COD ur ekonomiskt perspektiv:

COD ger lägre kostnader och snabbare vinster

COD är designad för att på alla plan vara ett kostnadseffektivt verktyg för våra kunder. Fast pris och låga inköpskostnader är bara en del av bilden.

Fakturering efter slutfört uppdrag gör att projektkostnaderna blir lätta att överblicka och administrationen förenklas.

Ur ett vidare ekonomisk perspektiv innebär den kortare utvecklingsprocess som COD möjliggör, att investeringarna för projektet förräntar sig snabbare. Produkten kommer snabbare ut på marknaden och får därmed ökade möjligheter att generera vinst.

Den omedelbara tillgången till spetskompetens är en rörlig kostnad, som ger varaktig ökad konkurrenskraft och långsiktig goodwill – vilket grundar ett värdefullt förtroendekapital.

Lämna virtual reality och ta direktkontakt med COD! Knappa in www.cod.nu

Figure 6.13. The third page of the COD information folder as an example of style and layout

We used the opportunity to describe the company, Frontec Research & Technology AB, and interesting projects like our involvement with Rosetta, the ESA deep space probe. We further told our readers about FIOS, the Frontec Institute of Science, headed by Professor Stig Ottosson. All the departments were also described. However, the over all weight was on COD of course.

To augment the text we also produced a CD with a nice cover. That opened like a book: one leaf to the left and one leaf to the right, figure 6.14.

Figure 6.14. The COD CD cover opened with the CD disk in the center

The text on the CD cover described COD very briefly and then urged the reader to put the CD in his computer's CD player. The COD presentation on the CD then started and took the viewer through an eight-minute tour of COD.

In total, we produced 1500 CD and information folders. Circa 1350 of these were put in envelopes together with a letter and mailed to customers and potential customers. At this time, we also gave away T-shirts with the COD symbol printed on the front, to customers that we visited. The T-shirt was an appreciated gift to new employees. It was intended to work as a gratis commercial advertising for COD.

We had our first customers using COD. The very first was the world famous camera manufacturer Victor Hasselblad AB. They used COD for modeling stress and displacement of a camera house by use of FEA, figure 6.15.

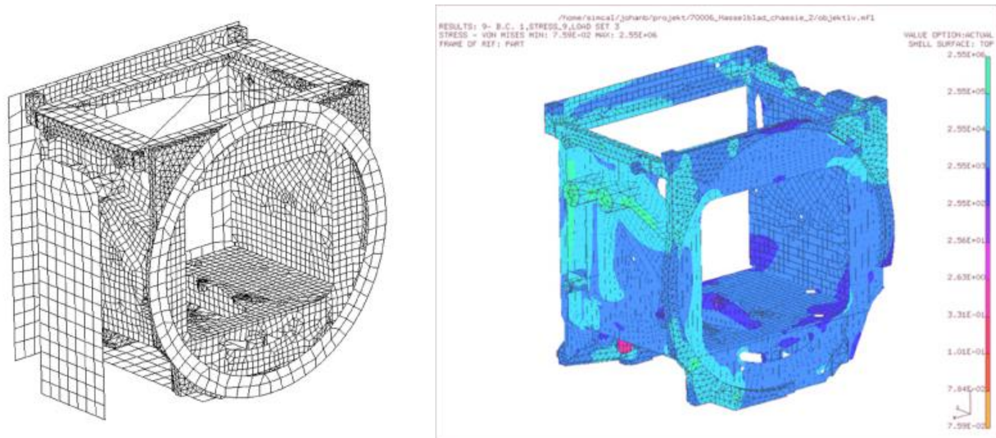

Figure 6.15. A camera house analyzed with FEA through the use of COD

Another early COD customer was SAAB Automobile, the well-known manufacturer of sporty prestige automobiles.

6.3.22 Weeks 46-52: Product placement

COD activities were now low for all project members because we thought that we were finished. COD was up and running, we had no reports of any bugs, and we thought that we had done our job. Now it was up to our sales manager and the department managers to sell and endorse COD. We expected others to take over and make a success of COD since it was such a good idea.

On 1999-12-10, I gave an interview to Lars Erik Brandt, editor in chief of *Verkstäderna*[49], the leading periodical on manufacturing company issues. What initiated the interview was the press release I had sent out and other supplementing material, such as ready to use text and pictures, attached to the press release. In a way, this was product placement. It was hoped that the coming article (Brandt 2000) would further raise interest for COD among our customers and in the market as a whole.

6.4. Project ends

In this description of COD, I have chosen to let the project end at years end because I was no longer writing up time on the COD account. However, if we by COD project mean the time the team was up and running, then *the project lasted for no more than 12 weeks*, which is about half of what was thought needed for a commercial e-business website project among informed individuals, at the time.

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[49] http://www.verkstaderna.se/ 16500 printed monthly, read by 40 000, distributed to 3000 manufacturing companies.

7. Analysis and discussion of Cases 1&2

7.1. Analysis and discussion of Case 1

The rack project and its aftermath are in the author's experience untypical of what most engineering consultants do. Only rarely are such projects bestowed upon consultancy companies since most of their business, at least in the Nordic countries consist of low-level work such as building CAD models, or writing software code. This can be seen in the vulgar nicknames given to consultant engineers; *CAD slaves* for mechanical engineers and *code apes* for computer programmers.

Prosolvia AB differed from other companies in its field by having a comparatively well educated workforce. About 75% had an M Sc degree or higher and 15% held a PhD. Further, as has already been pointed out, Prosolvia AB was a leading provider of virtual reality solutions. As regards the author, he had managed some very special and advanced development projects prior to joining PRT, the daughter company of Prosolvia AB. It probably was a combination of these factors that made Weibulls give PRT their business and for Volvo Olofströmsverken (VOV) to continue talks with Weibulls resulting in the 3166-project, as described in chapter 5.

7.1.1 The rack business situation

Since we do not know what thoughts and intentions the different players harbored, we can only speculate. There are some interesting circumstances though. First, the rack industry in Sweden was characterized by

- Low technological level with sequential development and several interfaces to the customer company (primarily VOV and Volvo Car Corporation (VCC)).
- Small local workshops, each with circa 8 employees and 2000 000 € annual turnover. The Swedish automotive rack market had a total annual turnover of 18 000 000 € from Swedish suppliers and 2-3 times more from abroad.
- Local & sub optimization: typically, a local consultant designs a special solution and a local "black smith" manufactures. Many different solutions e.g. electro zinc plating, hot dip zinc, wet paint, and powder paint.
- Larger orders are purchased from abroad, for example Spain, France and Germany.
- Rack development has low priority and status.

The last point may need an explanation: An automobile manufacturer will focus on developing next year's model rather than some packaging material. Therefore, while top-level management has their attention focused elsewhere, managers concerned with transportation of goods are given lots of freedom. This could perhaps explain the rumors (to the author's knowledge completely unsubstantiated) of bribes being common.

It was also clear to those involved that future rack business would be characterized by:

- Shorter product development cycles (this was stressed by VCC and VOV on several occasions).
  - CAD solids (Catia v4/v5, mandatory according to VOV), robot and production simulation (already started by VCC).
  - VR technology (prototypes and production simulation).
- Modularization (Ford was already there).
- Total transport cost of goods, including purchase-, service-, and transport costs over the life span of the rack was being studied by VCC logistics specialists and purchasers. Simulation software was under development.
- Identification and traceability (the present printed Odette form would in the future be superseded by a transponder on the rack).
- Environmental concerns would be more important, demanding lower weight racks, recycling, etc.

The rack business clearly was complex and potentially full of surprises. The many downsides of that were not entirely perceived by the Weibulls/PRT team. For example, since they were new to this business, they did not know of dependencies and ties of obligation between the players[50], of all the "who has done whom a favor[51]". Furthermore, it was obvious that small "village black smiths" could produce and sell present-day racks in small quantities at distressingly low prices. It would be very difficult for a purchaser to argue in his organization for the purchase of a more expensive rack even from a much more competent source.

VOV demanded Catia workstations, participation in product development, quick response times, etc, but would probably be reluctant to pay extra for that. Parts commonality is a way to lower cost but such a solution will not yield an optimum single rack as regards performance. That would with more certainty, come from a special design.

The situation was tough; Weibulls certainly should not play on the "black smith" field, but would probably have to be content with "black smith" pay, at least in the

[50] This can be seen as a shadow system, sections 3.2, 3.3 and 3.7.1

[51] The importance of the complex system's history, section 3.3 Complexity.

beginning. In hindsight, it is questionable if Weibulls really had the financial muscles for that. To become what was asked for, Weibulls would have had to invest in several Catia workstations and employ several design engineers, perhaps a purchaser as well, strengthen the sales department and invest in production capacity without having a single order for racks. From a business point of view, it probably was a mistake not to follow through on the acquisition of rack producer JIWE AB.

At Weibulls, at the time, they were committing themselves to heavy investments in building a production unit in Poland. This required considerable management attention.

What possibly was an early indication of the true ambition in Weibulls' organization was when the project leader wanted to meet with all production planners, production managers and design engineers that would become involved in rack production and had to be content with two design engineers, who were rather uninspired by the rack idea. This might have been the teleological aspect[52] of the shadow system[53] that showed itself. Maybe that incident revealed the true intentions of Weibulls.

From a complexity point of view, this can be seen as the presence of a strong attractor[54] that locks-in Weibulls in their traditional/entrenched organization-business-situation. In such a case, only a forceful perturbation, much stronger than can be achieved by a hired hand/consultant, can move the system to a new attractor, and especially if the system is far from the edge of chaos.

In this case, the formal organization of Weibulls tried to look like a competent rack producer in order to get orders for "low tech" racks and be "high tech" paid for it. In the end the commitment was not strong enough to compete, not with the local "black smiths" for their days were numbered, but with the rack specialists in continental Europe. Regardless of any actions by the project leader, he could not have changed that.

7.1.2 Prosolvia's business

From what initially looked like a six-week one-man job grew out several projects over a period of approximately a year and a half. With one of them being PRT's most profitable ever.

Could PRT have done more for Weibulls? This author doubts that. He thinks that PRT took Weibulls as far as they could. It was because of Weibulls themselves, foremost their lack of wholehearted commitment and hesitant attitude towards in-

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[52] Section 3.4.1 Organizations are teleological
[53] Sections 3.4 Organizations as complex systems, 3.8.1 Group problems
[54] Section 3.3.1 Complexity and complex systems

vestments, combined with the very structure and politics within the rack market that their effort to become a rack producer failed.

7.1.3 Product development findings

This project was typical in the sense that product development follows the business opportunities as they unfold. Product development is used for to cater for business needs, trying to profit on fleeting opportunities as they appear. That can be called business development by aid of product development. In a way, it is as if one investigates possibilities. In such a situation, there are no stable conditions as demanded by static PD methods, but flexible adjustment is important.

The overall lack of commitment from Weibulls as regards allocating recourses has already been discussed, but perhaps they should have put in a greater effort in direct sales activities (very energetic courting of purchasers, quoting very low, selling at a loss, etc). It seems probable that if Weibulls had succeeded in landing an order for say 200 racks, then they would have had a chance to prove themselves as a rack producer.

It is interesting, at least to the author, that *sale is not part of product development theories* such as SE/CE, SG, or IPD, except as a last step in IPD (figure 2.7) when production starts. In one renowned model, sell even comes after manufacture (Pugh 1996). Only DPD theory talks of the importance of early sales activities (Ottosson 1999B).

7.1.3.1 Time schedules

The first time schedule was completely incorrect after four days. The next Gantt chart held for just a few days. In the end, all time schedules were abolished. This was natural since the team *chased opportunities as they emerged*. Flexibility was therefore very important and thus the "drive by the seat of ones pants" attitude combined with regular reporting of activities and results as well as discussions of future actions. You might say that planning and plans, in their different roles[55], were substituted by intense dialog.

7.1.3.2 Budget

It is unknown whether Weibulls had a budget for the rack initiative. The project leader did not have a project budget. However, he had full authority to spend money as he pleased in the project, which in a way could be called an unlimited budget.

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[55] Section 3.7.1 Planning

7.1.3.3 Methods of engineering design

The author has not covered the technical details of the concept development and detail design that they did at PRT for their client Weibulls. The building of CAD models was routine and looked the same as everywhere else. What differed was the creation of concepts prior to CAD modeling.

The project leader used ideas from DPD theory, such as thoughts and contemplation (BAD) then pencil sketches (PAD) followed by, in the case of the console pillars, cardboard models (MAD). Especially the cardboard models were very effective tools both for generating a sound design and for explaining and conveying ideas to the design engineers at PRT.

In the designing of racks, the team produced several innovative design solutions; like using elasticity and plastic flow to compensate for the wide tolerances of rectangular tubes when designing the deep drawn corner pieces. However, such engineering efforts are of little use if there is no business fit.

7.1.3.4 PD theory and Case 1

None of the common PD theories is applicable to Case 1 as a whole. There were no stable conditions as demanded by SE/CE and IPD[56]. Gates[57] would have been completely irrelevant. Applying gates would have been an attempt at putting a straight-jacket on the situation, and the situation would not have allowed that. There could hardly be constructed a value function to be optimized. There was not even a clear mission statement. The situation is best described by figure 2.1 with the exception that the Weibulls/PRT team was not sure of the existence of a real business opportunity. That was what they tried to establish.

Case 1 represents an open complex system, with a multitude of agents who were partly unknown to the Weibulls/PRT team, with definitely unknown agendas. It was difficult to get a hold on the business logic and to create a fit between Weibulls and Volvo Car Corporation. Weibulls business intelligence was poor or non-existent. There was little analysis prior to action, for how could there be without information? The only way to gain information was to take part in the game, to act in order to learn and discover new facts as events unfolded.

Thus, Case 1 very much resembles an EKP[58] situation where traditional PD methods fail, and one acts in order to gain knowledge of the situation. Then that newly gained knowledge may force a reevaluation of earlier standpoints yielding a reorientation[59].

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[56] Sections 2.3.3.1 SE, 2.3.3.2 CE, 2.3.3.3 IPD

[57] Section 2.3.3.5 Stage-and-gate processes

[58] Section 3.6 EKP – emergent knowledge process

[59] Section 3.7.3 Aim and purpose of strategy

We are in the un-ordered part of the Cynefin model[60] where relations are complex. In retrospect there is coherence, but not when one is in the middle of actions. The correct tactics here is probe-sense-respond. Such action is in accordance with maneuver thinking[61], which incidentally is a basis of DPD. It seems that DPD with its stress of dynamic action is the only PD theory applicable to Case 1.

It is illustrative to discuss the situation with aid of the Boyd loop[62] (figure 3.3). How the Weibulls/PRT team understood the business situation depended on their observation, which in turn depended on their actions, which were guided, via decisions, by their orientation. What they tried was very much to find a viable understanding, so that Weibulls could be oriented slightly different, or moved out of its present attractor[63], in order to incorporate the development and production of racks. For to reach this final state, or new attractor (of Weibulls being a rack producer), at least part of the organization must undergo a number of intermediate quick reorientations. The inability to do that is one explanation for the failure to become a rack producer.

A way to incorporate rack production without a reorientation of the Weibulls organization would have been to follow through on the acquisition of JIWE AB as was intended from the beginning.

7.2. Analysis and discussion of Case 2

Less than a year after the COD project was finished, FRT was subject to a hostile take-over. FRT employees would, one after the other, give notice of termination of employment with FRT, because Sigma AB, one of FRT's competitors, had secretly invited large groups of FRT employees to secluded recruitment meetings and there told them to come over to Sigma. The majority of mechanical analysts wrote a letter demanding that Frontec should sell FRT to Sigma AB. If not, they would leave FRT.

Eventually Frontec, the mother company of FRT, gave in and sold FRT to Sigma AB. FRT was split up. The mechanical design and production engineering departments were merged with a newly formed Sigma company called Epsilon Development. The mechanical analysis department was merged with Hightech Engineering AB, which had recently been acquired by Sigma, and already had a large analysis department. The author personally spoke with the CEO of Hightech Engineering AB, informing him of COD and the author's view that in the future all mechanical

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[60] Section 3:5 Order and un-order.

[61] Section 3.7.4 Maneuver thinking

[62] Section 3.7.3 Aim or purpose of strategy

[63] Section 3.3.1 Complexity and complex systems

analysis jobs will be handled in processes similar to COD. The CEO said that he hoped not.

The author left Epsilon Development three months later for Bertrandt Sweden AB, a subsidiary of Bertrandt AG, which was a buyer of FRT that the author had recommended and would have preferred.

In the turbulence before and after the hostile take-over and without a strong advocate, the COD ideas were doomed. Six month after the take-over, the COD server was closed and the equipment was used for other things. However, there are perhaps additional reasons for the ill fate of COD, and that is the temperament and personalities of mechanical analysts and strategic and tactical mistakes.

7.2.1 Engineering design vs. Mechanical analysis

There are definite differences between mechanical design and mechanical analysis. In design, geometry is a variable, a parameter with which to play, but in mechanical analysis geometry is a given. In the experience of the author, this is reflected in the two work roles. Somewhat exaggerated, design engineers can be said to be extrovert fast movers, whilst analysts are more introvert and find their self-appreciation in the precision of their analysis results.

On a more basic level, there might be a problem with highly educated people, the analysts, just producing basic input to the decision-making of often lesser educated, however more artistic, design engineers. The analysts have a tendency to isolate themselves with their, from a complexity viewpoint simple, albeit abstract, theories, showing very little regard for the complexity and creative challenge of engineering design. In the author's experience, it is much easier to find a design engineer with some mechanical analysis capability than the other way round.

A special nicety with COD was the fact that with this new process, FRT did not sell hours but results. The workload was deliberately hidden from the customer and in communication with the customer; there was only talk about results, delivery date, and price. The motive for this was simple; freedom to negotiate as good a bargain as possible for FRT.

Say for instance that the customer when receiving the COD-pilot's quote says, "This is too expensive for me". Then the COD-pilot would answer:"I understand, but there is quite a lot to do here for the moment. So can you wait a little with the results, then I can perform your analysis later when there is not so much to do. That way we could lower the price, is that OK?" Or the other way round, say that the customer says:" I'm in a hurry can't you do this faster", then the COD-pilot would answer:"there is quite a lot to do, we are very busy. I could maybe put aside other pending work, slip in your job in-between other jobs, and call in extra people to help, but that would cost more. Is it OK if we charge xx € for the job?"

The described scenario, it seems, would never happen with the typical mechanical analyst. He or she does not like to bargain. We are possibly dealing here with a conflict between personal needs and organizational demands[64]. This fact was something that the project initiator had completely missed when he designed the COD process. He had thought that the possibility to close good business deals would be more important to COD-pilots than the anxiety they experienced when dealing with customers.

Another nicety with COD was the idea of numerical estimates. The simplest strength of materials estimate is F/A or divide force by area. This gives a very, very rough estimate of how stressed a part is. The idea with numerical estimates was to perform simpler, faster, cheaper FEA and CFD analysis than usual in order to save time and money and allow for more design iterations. To put in just enough of work, to give an answer with the right precision, not with five correct digits if one or two is sufficient, require skill and you could say *Fingerspitzengefühl*[65].

In their reports, mechanical analysts like to give recommendations to the reader who normally is a design engineer. Sadly, these recommendations often bore witness of a stunning lack of understanding of the design problem and how to deal with it.

In hindsight, it is obvious that the wrong conclusion had been drawn from this. It had been assumed that the analysts would cherish an opportunity to get more involved with the design process and use their judgment in a new and wider way and to adjust the analysis more to the actual need of the design engineer. They did not. Instead, the possibility given them perhaps made them aware of their insufficient competence in engineering design. However, more important, it also threatened the slack between jobs that they were accustomed to enjoy. They were brilliant people, so maybe they saw through the COD-initiative's intention to remove slack and therefore felt reluctance towards COD. Maybe it was a case of the shadow system[66] striking back.

7.2.2 Giving the right impression – office politics

The project leader probably should have presented another picture of COD and its history than he did at the presentation to the FRT employees in week 36. He had chosen to describe truthfully the COD idea; why they did what they did and how it was supposed to work. Possibly another narrative would have worked better.

The project leader also put on stage the COD team. By letting the audience learn what a wonderful effort this group had put in over the last three months, the project

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[64] Section 3.8.1 Group problems

[65] Section 3.7.4 Maneuver thinking

[66] Sections 3.4 Organizations as complex systems, 3.5 Order and un-order, and 3.8.1 Group problems

leader wanted the team to be proud of their achievement, and above all, feel appreciated by their project leader and by management as a whole.

Hans-Åke, the CEO liked to talk to an audience. However, since he was not entirely in tune with the COD concept, he was slightly beside the point, thereby he diluted the intended message and blurred our focus. The project leader should have cut down on his time on stage; he should have controlled Hans-Åke better.

Hans B, the head of mechanical analysis that had been so enthusiastic in the very beginning, the project leader could have handled better. Hans had enthusiastically tried to create a symbol and a name for "Snabba Skott", something that had not turned out well. His suggestion therefore had been rejected and that probably hurt him much more than he showed, or the project leader understood. The project leader could perhaps have repaired that by putting Hans on stage, letting him shine in front of everybody, taking the major credit for COD. By putting the stage light on Hans B, it would have been harder for him to back down from COD. The omission of the project leader was probably a strategic mistake.

The project leader could have involved the FRT sales/market manager right from the start, or at least have kept him well informed. However, that would possibly have been too cumbersome for the project leader to do, for the sales manager was not a man used to play with ideas. Besides, this was not felt as very important at the start, because in this project there were so many things to think of, so many problems to solve, and so many obstacles to circumvent. Nevertheless, it still was a tactical mistake.

7.2.3 The team

There are five simple requisites that must be in place for a team[67] to be successful.

A real team. In this case, the project leader did have a real team. Team members wanted to be on the team, because they had been invited to participate and they were chosen for their expertise and personality. The goal was to recruit team members that complemented each other's competence. The project leader had in his mind the complete team when he decided whom to invite. In the mind of the project leader, he had pictured how the team would work together.

There is a risk of achieving too little cohesion in a group of disparate talents. However, by stressing tempo and the time-box principle team members were fully occupied with project work. Therefore, their minds were not allowed to wander off thinking about other things or taking part in other projects. The special COD project room[68] also worked against centrifugal forces in the team as it help minimize distrac-

[67] Section 3.8 Design the team
[68] Section 2.4.1.1 Collocation

tion during work. However, the strongest cohesive factor no doubt was the vision, the compelling direction.

The compelling direction, which was to create COD, a work process and tool that would help create better designs that would reduce waste of valuable resources and lead to job enrichment. COD was good for the individual, the company, and the world as a whole. What more compelling direction can a team have?

There was an enabling structure. There was a sound project organization in place, with clear statements of responsibilities and division of work. The culture was in place. Here the author sees culture as "…a set of norms that determine what is ordinary, or what is canonical…" (Jönsson 2004).

There were clear directions given about communication, when and whom to report to, the structure of the project area on the net server, etc.

The team had a project room dedicated to COD only. They had all the software, computers and whatever they could need.

Supportive context in this case means a free flow of information, and a forgiving atmosphere where mistakes are allowed if they are the result of meaningful risk taking. There were no monetary rewards as such, but the gratification at the end of having done something extraordinary. It was rewarding to be allowed to learn and to create something new.

The project leader gave an order that a so-called Easter egg should be placed on the website. By clicking on a special area, not larger than a few pixels, a window came up with the team members' names, so that they later could prove their participation and get credit for their job wherever they were, just by clicking that spot.

Expert coaching. The author thinks the team received expert coaching by having a competent project leader and by the advice and discussions that were available in a "second line of command" which was the head of the Frontec Institute of Science.

The project leader had started the team by inviting team members to a long lunch. Because there is something with eating together, with sharing food that goes deep down into the very essence of being human. In the Christian religion, there is communion and the last supper. Among so-called primitive tribes, we find that it is common for them to sit together for meals, around food that they have gathered or hunted, and to share that food between themselves. The food is passed around several times, just as we do at the table. At birthday parties we eat, at Yuletide we eat, at Midsummer we eat, etc.

A family eats together. In just the same way the project leader wanted to give team members an opportunity to bond by having them eat together at the start of the project and occasionally during the project.

Individual team members were good at bonding. Inger and Charlotte came from an advertising agency and really showed great professionalism not only in their work but also in handling the social aspects of the project, as did several others.

Typical for the interaction in the team was a free flow of information, mutual respect, curiosity, and a willingness to go forward, somewhat of a restlessness to get things done. When team members went into each other's competence areas, they showed tactful respect and consideration. The team functioned harmoniously and was very efficient. Leading that team was a very gratifying experience to the project leader.

7.2.4 Complexity aspects of the team

According to the complexity based theory of self-organization in human systems by Eoyang (2004), self-organization requires three interdependent conditions: *container, significant difference,* and *transforming exchange*.

Container is the boundary that distinguishes a self-organizing system from its environment. There are three basic containers that increase the probability for self-organization.

1. External boundary, or fence: a room, information system, membership criteria, etc. – *These factors were in place; the team had a project room, a dedicated reporting system, and a reserved area on the company server.*
2. A central attracting force: a magnet, e.g. a charismatic leader, a clear and shared vision, and a desirable resource. – *The team had (maybe) a charismatic leader, definitely a clear and shared vision, and a desirable resource in the form of an interesting project to take part in*.
3. One-to-one attractive forces, affinity-like containers: e.g. gender, ethnic identity, shared language, and trust. – *There was a liking of each other amongst the team, but the strongest attracting force was probably the chance to participate in an interesting and unique project*.

Significant differences. Within a container, difference along one or several dimensions between agents establishes a potentially generative tension. – *Team members had been elected based on their disparate talents and differences as regards competence and temperatment.*

Transforming exchange. Language is the most obvious, but any transfer of information, energy, or matter can function. The exchange becomes transforming when it affects the self-organizing processes within the agent, crossing containers from system of agents to the agent as a system. – *The collocation of team members in the project room and other measures, such as project meetings created a massive exchange of verbal and non-verbal information between team members*. *The disparate talents, abilities, and* *expertise together with the need for cooperation within the project created a transforming exchange*[69].

The system has self-organized into coherence when stable system-wide patterns are maintained for some time. Internal dynamics might hold the system in a stable state by opposing change or emergence of new order. **Coherence** is characterized by:

- Meaning is shared among agents
- Internal tension is reduced
- Actions of agents and sub-systems are aligned with system-wide intentionality
- Patterns are repeated across scales and in different parts of the system.
- A minimum amount of energy of the system is dissipated through internal interactions.
- Parts of the system function in complementary ways.

All of the points above were in place in the project team. *In addition, when a shift in direction was called for, it was very easy to change the direction of the project.* A contributing factor to this was the fact that the team was guided by a vision instead of extensive project specifications and timelines. It is much, much, easier to move a vision slightly, than to rewrite specifications and plans. Visions and storytelling is one preferred way to influence an organization by a "complexity leader" (Olson and Eoyang 2001). Further, according to Eoyang (2004), when the system reaches a state of coherence, the available energy of the system is aligned and focused on system-wide behaviors, rather than diverse and disruptive behavior of individual agents or subsystem clusters; a fair description of the COD project team.

7.2.5 Planning

In the COD project, plans did not hold for long thereby confirming DPD theory[70]. Planning was done anyway, and for two reasons: first, time lines were used "politically" in order to influence and convince, and second as simulations[71] for creating estimates and preparing for future events.

There was a deadline and funds were limited. Therefore, time boxes were used, which meant that functionality that had not been implemented within a certain time was left for later. The important thing was to have a functional website up and running when the project closed.

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[69] An example: As a result of their participation in the COD project, Inger and Charlotte in their advertising agency hired a web designer. Web design is now an important part of their business.
[70] Sections 3.7.1 Planning, 3.6 EKP – emergent knowledge process, 3.7 Strategy
[71] Section 3.7.1 Planning

7.2.5.1 Time lines

There were timelines created in the early phase of the project. For the COD project leader, normally a senior project manager of FRT, it was standard procedure to create Gantt schemas in MS Project software and print them out on the company A3 laser color printer. The colorful diagrams were normally used to impress customers but worked for internal projects too. It was much easier to get acceptance for a project once there was a color printout of a Gantt chart.

Gantt schemas were not used in the COD project once it really got started. There really was no use for milestones since there was very little interaction with or dependence on objects outside of the team and activities in a Gantt chart would be either too late or too early since activities were driven by, and performed, in harmony with how the project developed. This was a result from using DPD and its control structure[72].

The team had a rough overall time plan, but the short term planning was done from week-to-week and day-to-day in accordance with how work developed.

It is interesting to compare Gantt schemas from weeks 11, 12 and 17 with the project leader's actual writing up of time on the COD account, figure 7.1.

[72] Section 7.3.2.1 DPD control structure, figure 7.2

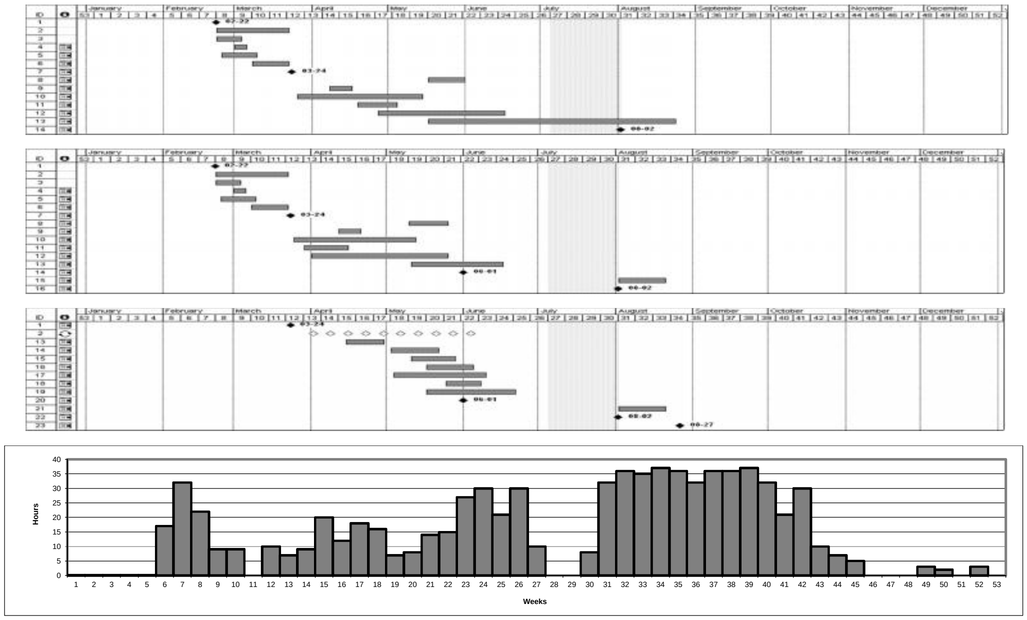

Figure 7.1. The graphs allow a comparison between Gantt schemes from week 11, 12, and 17 with the actual weekly hours the PL reported to administration

It is obvious that the plans are just a snapshot of what is believed at the time when the plan is created. If one looks carefully, it is possible to see differences between the two first timelines although they were created just a week apart.

There are those that advocate the maxim *plan the work and work the plan* (Forsberg 2000). That of course presupposes a continuous planning as no plan holds for long in a development project. Since action follows close behind decision, the planner might find it hard to keep up with activities as they develop[73].

7.2.5.2 Action plans

Action plans were used from the outset. They proved invaluable as a means to come to grips with the situation. Long before the COD project was staffed there were action plans in place. They came to function somewhat like a Work Breakdown Structure (WBS) (PMBOK 2000, PMI 2001). A WBS can be used for scheduling and for allocating responsibility. That is how the action plans were used at the start of the COD project.

Later, during the most intense phase, action plans turned into personal to-do lists and were no longer kept as project documents.

[73] Section 3.7.1 Planning

7.2.6 Marketing and Sales

The planning for sales of services and marketing of COD was less thorough than the development of the website. Planned market communication channels were: sales letters (letter, four page folder, CD), the Technology Fair in Älvsjö (Stockholm), and articles in journals (Brandt 2000, Bergh 1999, Lundgren 1999A and 1999B). Additional intended channels were the usual net of contacts that the department managers and the sales manager have, and spontaneous contacts from customers.

Since COD was a business innovation not only the selling part, FRT in this case, was affected but also the buyer or customer company. COD made bypassing customers' purchasers possible. The COD-initiator envisioned the following scenario. When planning a development project at the customer, they would allocate a certain amount of money for mechanical analysis for the whole project and then the design engineers would buy mechanical analysis as needed through COD without involving their purchasers. The important person here would be the manager of product development, not the purchaser.

The COD-initiator discussed this with Hans B, the manager of the mechanical analysis department, and got the impression that he agreed that e.g. midlevel design managers at Volvo Truck would have to be approached by FRT and be convinced of the merits of COD and persuaded to use COD.

FRT did not make that kind of contacts. The effort needed for to create necessary connections was not put in. FRT department managers were reluctant to do this. They did not appreciate this new disruptive business innovation.

The author strongly feels that COD would have been more successful if FRT had shown perseverance and a willingness to create new contacts in their customers' organizations. Perhaps one reason for COD not becoming a smashing success was FRT's poor selling activities or lack thereof.

7.2.7 Indecision without a strategy

> Among the maxims on Lord Naoshige's wall there was this one: "*Matters of great concern should be treated lightly*."
>
> Master Ittei commented, "*Matters of small concern should be treated seriously*." Among one's affairs there should not be more than two or three matters of what one could call great concern. If these are deliberated upon during ordinary times, they can be understood. Thinking about things previously and then handling them lightly when the time comes is what this is all about. To face an event and solve it lightly is difficult if you are not resolved beforehand, and there will always be uncertainty in hitting your mark. However, if the foundation is laid previously, you can think of the saying, "*Matters of great concern should be treated lightly*," as your own basis for action.
>
> Hagakure (Tsunetomo 2000)

The indecision of FRT's CEO during this project is striking. There clearly was no process or thoughts of product development. When the initiator of COD pointed out a way to grow in both turnover and profit he was met with bewilderment.

In a market economy, all healthy companies have survival as their first concern. In order to survive they constantly seek new and better ways to serve their market. They continuously change and adjust themselves to market preferences and try to take advantage of fleeting opportunities. This is sometimes called "dynamic capability" (Eisenhardt and Martin 2000). Actions are based in the companies' strategy, which is a natural consequence of the company culture.

One part of such a strategy is to strive for agility and to become powerful. Actually, such power can be measured. It can be seen as the sum of the power that each member of the organization has. Employee empowerment thus increases the potential for organization power. However, the individual power vectors must be pointed in approximately the same direction (Richards 2004). To achieve this is the obligation of top-level management. That was lacking in Frontec Research & Technology AB.

The COD project should have been supported fully or dropped. Neither was done. FRT was not a powerful organization, not because people shrank away from responsibility, but because they lacked direction.

Frontec AB, the mother company of FRT, was a software, web, and management consultancy company active in many countries. COD was the first Frontec e-business. It is somewhat of a destiny's quirk that this B2B Internet initiative came from the mechanical engineers of FRT – not from the myriad of web designers and software specialists of Frontec.

7.2.8 Product development findings

No amount of advice will help an organization to improve itself if such improvement methods expose or attack senior decision makers' greed, ignorance, or foolishness (Pech and Durden 2004). Surely, COD had no strong advocate inside the organization, no sponsor, when the hostile take-over was a fact.

COD was not the result of ideas that had naturally manifested themselves from within the mechanical analysis department. That was a weakness and it could explain the reluctance shown towards COD from mechanical analysts and the new management.

It is still possible to say though; that strong contributing factor to the commercial failure was too little sales efforts and the resistance from the shadow system. Neither of them are part of common PD theory. Here, DPD is partly an exception, since in this theory early sales are good. However, it seems that PD theory should incorporate some organizational theory and stress more forcefully the importance of early sales activities.

The project team was tutored on DPD theory right from the start. They were collocated; the team had been carefully designed, and was governed by self-organization (relying on ideas from complexity theory), which proved to create an effective and efficient team. They performed very well. So well in fact, that they were the very best team the project leader had ever managed.

7.3. Inferences of a general character

By categorizing the two described cases, some inferences of a general character can be made, and further, by comparing the two cases with each other and with theory additional inferences can be made.

7.3.1 Wish, want, and need projects

Product development projects can be categorized based on whether they are *wish*, *want*, or *need* based (Ottosson 2006). Need based PD methods require stable conditions, which a *need* based PD project may have if the project is short compared to market dynamics, table 7.1.

	Wish	Want	Need
Stable conditions	–	(✓)	✓
Unstable conditions	✓	✓	–

Table 7.1. Depending on project driver, there are stable or unstable conditions

A *want* project normally has unstable conditions, but can experience stable conditions under certain conditions, while a *wish* project always has unstable conditions.

It is debatable whether Case 1, the rack project, was a wish or a want project. In any case, there was no definite end to the project. From what initially looked like a six-week one-man job grew out several projects over a period of approximately a year and a half, as the Weibulls/FRT team chased a business opportunity.

The COD project, Case 2, was a want, bordering to wish, project, because although there existed e-business solutions at the time, indicating a need project, none of them were, or intended to be, a disruptive B2B solution of the kind that COD was meant to be.

Want projects usually have unstable conditions, and therefore often no definite end. The COD project had a predetermined end, which was unfortunate, since that project could have benefited from a continual, iterative, development instead of the single pass development that was done. (Already from the outset of the COD project, the project leader felt a single pass development to be insufficient. However, it was not politically possible to gain acceptance for an iterative approach. Because there was at FRT a quality-management inspired attitude of "doing it right the first time" and consequently iterations were seen as a waste of money).

It is common to find definitions of "project" as "having a definite beginning and a definite end" (e.g. PMBOK 2000, Bruce and Langdon 2000, Larssson 1998, Wisén and Lindblom 1997). However, a wish based PD project will never experience stable conditions and therefore will never have a preplanned, definite end, since from the outset one is not even sure of finding a viable solution.

An inference from Case 1 and 2 is:

- Wish and want projects usually have unstable conditions and should therefore have no definite end (in time).

7.3.2 Planning

Planning of a PD project usually encompasses timeline, action plan, budget, a plan for resource allocation, a responsibility assignment matrix, procurement planning, risk management planning, etc (PMBOK 2000). In Cases 1 and 2, due to their nature, the team used only time line, action plan, and budget.

Timelines. In Case 1, timelines were used at the outset as a conversation starter, and as bases for negotiations (clarifying and defining the agreement between Weibulls and PRT, and for negotiating resources internally at PRT). However, as the first time schedules were found to be incorrect after just a few days, they were abolished. Flexibility was very important and thus the "drive by the seat of your pants" attitude combined with regular reporting of results substituted timelines.

In Case 2, timelines were initially used politically, but were not used once the project really got started. There was no use for milestones since there was very little interaction with, or dependence on objects outside of the team. Activities in a Gantt chart would be either too late or too early since activities were performed in harmony with, and as a result of, how the project developed. We find that in a wish/want project:

- Timelines are just a snapshot of what is believed at the time when the plan is created.
- To gain flexibility time schedules should be substituted by reporting of results and an intense dialog.

Action plans. In Case 2, action plans were found to be invaluable as a means to come to grips with the situation. From the start, they can be used for scheduling and for allocating responsibility and resources. Later, during the most intense phase, action plans may be turned into personal to-do lists. We find that:

- In a wish/want project, action plans are very useful.

Budget. There was no budget in Case1, but the project leader had authority to spend money as he saw fit, which in a way is an unlimited budget. In Case 2 on the other hand, there was a budget, which the project leader had full authority over.

Without a budget and other resources, the project leader's actions would have been restricted. It would not have been possible to take advantage of fleeting opportunities as they appeared, and actions would have been slowed down or inhibited. From this, we infer that:

- In a wish/want project, in order to achieve high speed and efficiency, the project leader must have full authority over the project budget and other resources.

7.3.3 Sales

Case 1 consisted of technical development and marketing activities, but no direct, aggressive, sales activities, and yet, it was obvious that the project hinged on success in sales.

The planning for marketing of COD was less thorough than the development of the website. Since COD was a business innovation, not only the selling part was affected, but also the purchaser at the customer company. COD made bypassing customers' purchasers possible. The important person would be the manager of product development, not the purchaser, and yet, there were no direct sales activities during the project. This resulted in a loss of valuable feedback, and a chance to iterate, yielding a less efficient single pass type of development. We find that:

- Early sales activities are important for the proper execution and success of a wish/want PD project.

7.3.4 Complexity aspects

Generally in a PD project there is a multitude of multilevel "forces" such as costumers, natural laws, users, management, production process demands, etc, and feedback loops that makes the product development project complex (Kolenda 2003).

Case 1 represents an open complex system, with a multitude of agents who were partly unknown to the Weibulls/FRT team, with definitely unknown agendas. The Weibulls/PRT team did not know of dependencies and ties of obligation between the players[74], of all the "who has done whom a favor". The history[75] of the system that is so important for a complex system was unknown to the team. The only way to gain information was to take part in the game and act in order to learn. The project was in

[74] This can be seen as a shadow system, sections 3.2, 3.3 and 3.7.1

[75] Section 3.3.1 Complexity and complex systems

the un-ordered part of the Cynefin model[76] where relations are complex. In retrospect, there may be coherence, but not when one is in the middle of actions.

What possibly was an early indication of the true ambition in Weibulls' organization was when the project leader wanted to meet with all production planners, etc, and had to be content with two design engineers. Maybe that incident revealed the true, tacit, intentions of Weibulls. Possibly the culprit was the teleological aspect[77] of the shadow system[78]. Alternatively/and it was an indicator of a strong attractor in the form of entrenched organizational behavior.

Also in Case 2, the COD project, office politics, which reside in the shadow system, and personal agendas (also in the shadow system) determined the outcome of the project as a business. Thus, we can conclude that:

- A wish/want product development project is a complex system.
- The strength and character of the present attractor must be taken into consideration if the PD project affects the organization that harbors the project.
- It is important to be observant of the shadow system.
- Especially the teleological aspects of the shadow system can be a difficult change resistor.
- There is an excellent fit between the complexity-based theory of teams by Eoyang (2004) and the COD team.

7.3.5 General PD findings

For Case 1, the rack project, the IPD model from Andreasen and Hein (1987) is reproduced in table 7.2. The fields that the Weibulls/PRT team was concurrently active in are marked with light grey. It is obvious that the project was in all parts, or phases, of the IPD model at the same time, except preparation for production and production itself, since these activities depended on successful sales that never occurred.

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[76] Section 3:5 Order and un-order.

[77] Section 3.4.1 Organizations are teleological

[78] Sections 3.4 Organizations as complex systems, 3.8.1 Group problems

Phase 0	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Need	Determining the basic need	User investigation	Market investigation	Preparation for sales	Sales
	Determining the type of product	Product principle design	Preliminary product design	Modification for manufacture	Product adaptation
	Consideration of process type	Determining type of production	Determining production principles	Preparation for production	Production

Table 7.2. The IPD model (from figure 2.7) with those fields marked with light grey, in which the team was simultaneously active during Case 1

There was no ordered sequence of phases following upon one another. This is contrary to the assumption of SE/CE and IPD. *These models apply to an ordered world that did not exist in Case 1*. The stage-and-gate structure of Stage-Gate™ was likewise irrelevant to the project.

In Case 2, the specification developed or rather emerged from project activities. The organizing principle was self-organization.

Only DPD prescribes how to perform work through its rules of thumb[79] and that was valuable to the COD project. The traditional methods (SE/CE, IPD, etc) do not cover such low-level aspects. Stage-Gate™ is a control structure that is active only at the gates that occur at five times during a PD project. It is hard to see how that could have helped in Case 2.

One contributing cause to the ill fate of COD was the lack of a strong advocate inside the organization; COD had no sponsor when the hostile take-over was a fact

In the COD project, the project team was tutored on DPD theory right from the start. That the team managed to work according to DPD (apply the rules of thumb) proves that it is possible to get good results from teaching the team a theory before work begins. Thus, we can conclude that:

- Gates and a phased approach (as in SE, CE, IPD, and SG) are irrelevant to a wish/want PD project.
- In a wish/want project, the product specification emerges from project activities.
- To succeed, wish/want projects must have advocates or sponsors in the organization.
- It is possible to get good results from teaching the team PD theory before work begins.

[79] Section 2.5.1.1 DPD rules of thumb

7.3.6 DPD

It is noteworthy from a theoretical point of view that in DPD one at every step **makes full use of the latest gained knowledge** through continuous adaptation, use of the Pareto principle, shift between tasks, etc, which makes DPD an efficient new product development method. This also means that DPD can be said to rely on learning not planning (Cunha and Cunha 2002).

If DPD should be characterized by three words, they could be:

- Vision
- Tempo
- Self-organization

Vision. In especially new product development (wish/want projects) one aims at a moving, or emerging target, since the target may evolve as a result of development work (this is unstable conditions). When the project is guided by a vision instead of detailed plans and specifications and there is an empowered project team, then one gains flexibility/agility and the advantage that fleeting opportunities can be profited on. Further, unpredicted outcomes (the complexity of a PD project) and problems can be handled, because the vision helps align activities so that a minimum of non-productive work is performed. Vision clarity is positively associated with success in evolutionary and radical product development (Lynn and Akgün 2001).

In the COD project an additional benefit from guiding with a vision was found to be the ease with which the direction of a project could be changed, we find that:

- It is easier to change direction of a project guided by a vision than a traditionally guided project, because it is much, much, easier to move a vision slightly, than to rewrite specifications and plans.

Tempo. In DPD all activities are directed towards the most important activities for realizing the vision. The pace can be high since unnecessary (non-value adding) activities are avoided. It has been found in new product development that emphasis on speed cause development personnel to make more careful decisions, and to more effectively implement new technologies and techniques (Swink 2003). It was found in Case 2 that:

- Tempo yields a beneficial byproduct namely that thoughts, mental models, problems, caveats, etc, are kept current.

Self-organization. With an empowered team, it is possible to rely on self-organization when all team members are fully aware of the goal of the project. Self-organization results in every team member's judgment being put to use.

A common objection is "*if every one can do as they please, then they will run every which way*" and all command and control is made impossible. However, in the experience of the project leader of Case 1 and 2, the empowered team is guided by the vision and therefore utilizes their power to fulfill the vision. It was found that:

- If by chance anyone should take off in the wrong direction, then it is easy for the project leader to correct that person, much easier and more efficient than continuously ordering every team member about, as in traditional methods.

Flexible taking-advantage-of-opportunities, where team members' judgment supersedes the project plan, are only possible if team members are fully informed and aware of the overall goal, objectives, and deliverables of the project. The project leader must therefore allow and encourage initiatives from team members. Mistakes and errors should be tolerated if they are the result of meaningful risk taking.

Contrary to other methods, DPD achieves through a low-level prescription of simple rules of thumb a higher-level effect, in complexity theory called emergence.

7.3.7 Product development control structures

Although not given the lions share of attention in the description of Cases 1 and 2, the project leader actually, hands on, controlled the projects. To control a project is about leading people. Leading "…involves the ability to 'get things done.' It requires an understanding of both the formal and informal structures of all the organizations involved…." according to the Project Management Institute (PMBOK 2000, p 25), however that is also practically all they say about leading.

Other project management or product development sources may occasionally cover the subject in general terms over a couple of pages (e.g. Smith and Reinertsen 1995, Forsberg et al 2000). There may be plans with tasks ordered in sequence and diagrams with blocks and arrows, gates and milestone, but no explanation of how a project leader, hands-on, actually leads a project. It is like teaching a student pilot everything about a helicopter, except how to fly. This could be a reflection of the common "outside and from above" attitude found in PD research.

In general management literature there are many sources ranging from theoretical (e.g. Jaques and Clement 1994) to more hands-on books of "management tricks" (e.g Blanchard and Johnson 1984), and of course the military excel on this subject, e.g. dedicating more than 200 pages to direct leadership[80] alone (Larssson and Kallenberg 2003).

The general management literature, although helpful, has a somewhat limited value since there are differences between the jobs of being a line-manager and that of being a project leader. For example, a line manager has the right to hire and fire, and the power to determine a subordinate's salary and other benefits, none of which a project leader/manager normally has. Furthermore, often there is a struggle between

[80] Direct leadership is when leader and subordinate are in each other's immediate proximity.

project leader and line manager for subordinates' attention, because in a matrix organization a subordinate may have to serve two or more masters.

A literature search by the author, for "control of projects" (several differently worded search strings) yielded practically nil. This was unexpected, since from the experience of the author, one of the first things a project leader asks himself is "what tools are available to me for leading this team?", or differently put "how do I affect the team to go in the desired direction, how do I spot and stop social freeloading, how do I change the course they are on, etc?"

A project leader often reports to a sponsor or sponsor group that have at their disposal instruments for controlling a project. These can be said to map a control structure:

- The sponsor controls the project specification (the project contract, contract book (Ulrich and Eppinger 1995)) that may contain:
  - A mission statement, the main goal and purpose of the project
  - What specific objectives to achieve
  - Action plan and timeline
  - Team staffing and project organization
  - Resources (budget), contact persons, partners
  - Reporting: to whom, what, when, and how.
- Sponsor meetings, where the sponsor controls the agenda and generally sets priorities, as well as controls eventual additional funding, and sets the "rules of the game".

Likewise, the project leader/manager can "set the rules" and decide about reporting and meeting structure for his project team. These subjects seem not to be treated in the literature, except for DPD, for which weekly reporting is a requisite activity (Ottosson 1999B).

In neither Case 1 nor Case 2, was there any explicitly designated sponsor group or sponsor. In Case 1, there existed the usual business documents: a quotation and an acceptance of quotation, etc, but no other documents of agreements. There was no written and agreed contract book for the project. There was however an intense dialog between the project leader and Weibulls' CEO. In this case, the CEO could be said to function, to some extent as a sponsor.

The few briefings that the project leader had with the FRT CEO regarding Case 2 can be seen as a project leader reporting to his sponsor. However that would not be entirely correct since, normally, a sponsor has a vested interest in the project. This was not really the case at FRT, where the best improvement idea of the month, was awarded with two cinema tickets. Beyond that, FRT had no procedures for handling change. This may seem remarkable, but is not unusual in the experience of the author. Who has also experienced, in other circumstances the opposite, namely that his projects have acquired regular attention of the company board of directors. In these cases, the projects have been technically and commercially successful. From this, we infer that:

- PD projects can benefit from the attention of top level management, and there should be company wide procedures in place to handle the PD project and integrate its result with line organization activities.

7.3.8 DPD control structure

The control structure of DPD and its effectiveness, as described in this section, was experienced by the author in the normal course of his management of development projects using DPD methodology, but especially in Case 2.

A DPD project is controlled from above through a progression of culture, strategy, and plans. Here plans are born out of a strategy, which in turn is dependant on a culture that allows and fosters such strategy, figure 7.2.

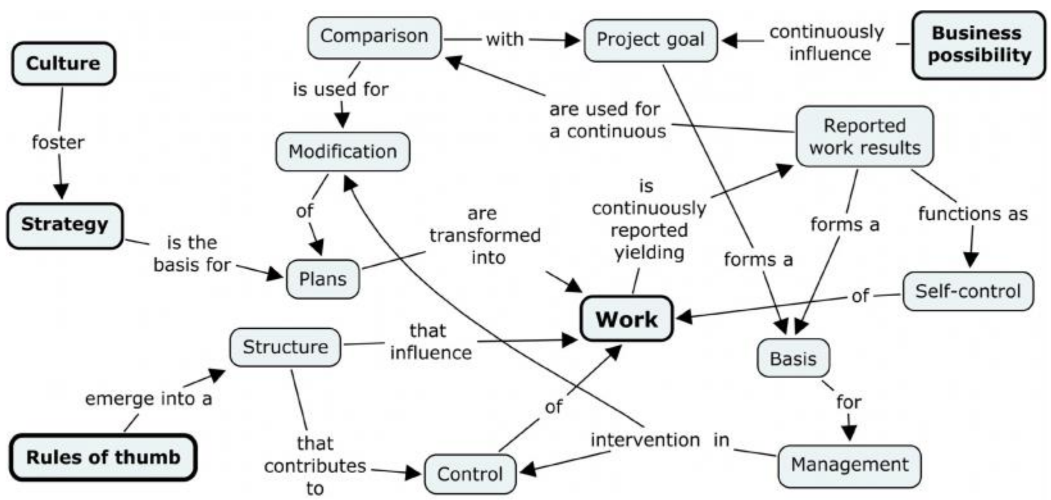

Figure 7.2. Principal control loops of a DPD project.

The DPD rules of thumb result in an emergent structure[81] that influence work and thereby functions as a control of work from below. (Example: the 80% rule is often perceived as "just do 80% right the first time", leading to an iterative attitude to PD and engineering design that markedly affects the way people work). This contributes to the control of work, together with guidance from plans and traditional management interventions.

[81] See section 3.3.1 Complexity and complex systems and 3.4.2 Self-organization and emergence.

The main control loop is work – reported work results – comparison – modification – plans – work, but also work – reported work results – self-control – work, which builds on the internal motivation of the individual and is a very powerful control mechanism[82] (Hackman 2002, p 95). Additional control loops are work – reported work results – management – modification – plans – work, and work – reported work results – management – control – work. It is the experience of the author that this very strong and efficient control structure, which seems to be unique to DPD, contributes to the effectiveness and efficiency of DPD.

It is worthy of note that the business possibility may *continuously* influence (if one so pleases) the project goal (moving target, unstable conditions). Work is *continuously* (daily or weekly) reported (scrums[83], email, dedicated website, etc) so "reported work results" is always kept up-to-date, allowing for an almost real-time control of the project. A shift in business possibilities therefore very quickly affects work, especially since team members are empowered to use their judgment.

7.3.9 Stage-and-gate control structure

We can see from figure 7.2 that by removing those parts that are specific to DPD, which are rules of thumb, continuous reporting of work results, business influence on project goal (moving target), and comparison and modification, most of the control structure disappears. What is lost is foremost the feedback loops and that which remains is the weak control structure found in other methods such as SE/CE, IPD, SG, etc, figure 7.3, which shows the weak control structure of a stage-and-gate process.

[82] This is in harmony with ideas of complex systems, section 3.3.1, and how they can be influenced.
[83] A scrum is a short (10-15 minutes), daily meeting where teammates report progress and problems.

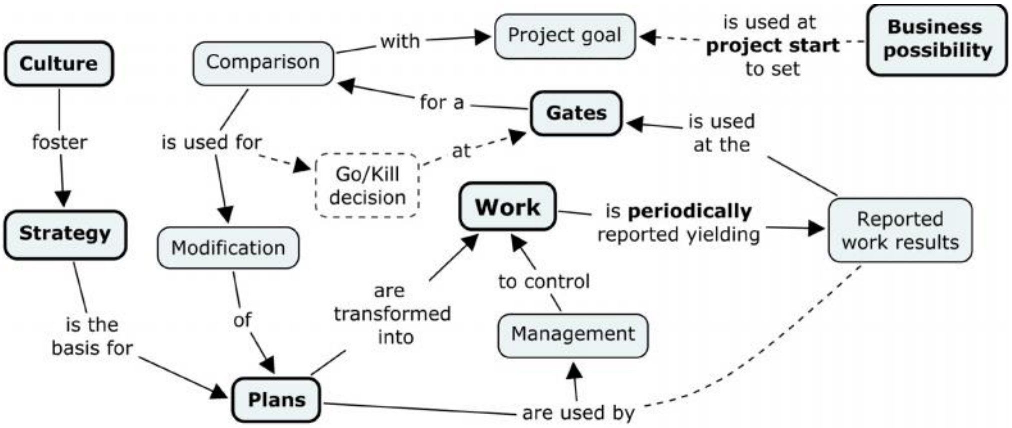

Figure 7.3. Typical control structure of a stage-and-gate process

The control structure of a stage-and-gate process has one control loop, and that loop works only at the gates. For the remainder of the time there is reliance on what risk being outdated reports of work results and plans. The business possibility only influences project goal at project start (stationary target) and plans are only modified, if at all, at gates. This is a "plan the work and work the plan" kind of control structure.

In biological evolution, species rid themselves of those parts of their nerve system for which they have no use. For example, if they live in complete darkness, they lose their eyesight. Likewise, one can argue that a PD project, seen as an organism, need not have a very developed nervous system if conditions are stable, the environment unchanged over the life of the project, and team members perform perfectly based on perfect knowledge. We can have many of these points, but not the last; perfect knowledge is not available (and probably not perfect team members either). However, even if we could, that would not suffice, as we know from complexity theory. Perfect knowledge does not make perfect plans possible. Therefore, the stage-and-gate control structure is always insufficient, but the more so, the more and the faster conditions change.

This has unintentionally been discovered in real life applications. The author has come across companies that in their quality system specify a stage-and-gate PD process, and when asked, they strongly state that they use a clean stage-and-gate process. However, in reality, because they feel the need, they use a modified or hybrid form, where the steering group that should be called in only at gates, actually functions as a sponsor group. This sponsor group calls on the project leaders to give frequent reports of project progress and feedback between gates.

However, even such a hybrid model would not have functioned well in Cases 1 and 2, because what is missing between the described hybrid form and the DPD control system proved to be essential.

7.4. Need, want or wish

The two cases described in the thesis were both wish/want projects and therefore observations are restricted to those project types. For wish/want PD projects, it was found that:

- Gates and a phased approach (as in SE, CE, IPD, and SG) are irrelevant to a wish/want PD project (section 7.3.5 General PD findings).
- Wish and want projects have unstable conditions and should therefore have no definite end (in time) (section 7.3.1 Wish, want, and need projects).
- Early sales activities are important for the success of wish/want projects (section 7.3.3 Sales).
- To succeed, wish/want projects must have advocates or sponsors in the organization (section 7.3.5 General PD findings).
- Timelines are just a snapshot of what is believed at the time when the plan is created, therefore to gain flexibility time schedules should be substituted by reporting of results and an intense dialog (section 7.3.2 Planning).
- In a wish/want project, action plans are very useful (section 7.3.2 Planning).
- In a wish/want project, in order to achieve high speed and efficiency, the project leader must have full authority over the project budget and other resources (section 7.3.2 Planning).
- In a wish/want project, the product specification emerges from project activities (this is a confirmation of DPD theory, e.g. Ottosson (1999B), (section 7.3.5 General PD findings).

8. Conclusions and outlook

In this final chapter answers to the research questions from chapter one are summarized and an outlook for the future is given.

8.1. Answers to research questions

1. ***What complexity aspects of product development, can be found?***

There are many feedback loops (figure 7.2) as well as a multitude of multilevel "forces" such as customers, natural laws, users, management, production process demands, etc, acting on a product development project, making it a complex system. PD projects often are in the un-ordered, complex part of the Cynefin[84] model. Further, it was found that:

- It is important to be observant of the shadow system (section 7.3.4 Complexity aspects).
- Especially the teleological aspects of the shadow system can be a difficult change resistor (section 7.3.4 Complexity aspects).
- There is an excellent fit between the complexity-based theory of teams by Eoyang (2004) and the COD team (section 7.3.4 Complexity aspects).

2. ***What requirements for successful execution of PD projects, can be found?***

It was found that the dynamic product development method known as DPD was able to handle the complexity of Cases 1 and 2, basically because DPD is based on learning instead of planning, and because DPD relies on self-organization, tempo, and vision, yielding the following effects (section 7.3.6 DPD):

- Self-organization: If by chance anyone should take off in the wrong direction, then it is easy for the project leader to correct that person, much easier and more efficient than continuously ordering every team member about, as in traditional methods.
- Tempo yields a beneficial byproduct namely that thoughts, mental models, problems, caveats, etc, are kept current.

[84] Section 3.5 Order and un-order

- It is easier to change direction of a project guided by a vision than a traditionally guided project, because it is easier to move a vision slightly, than to rewrite specifications and plans.

The shortcomings experienced in Cases 1 and 2 were not attributable to DPD.

3. ***Which improvements to the dynamic product development (DPD) method can be proposed?***

Although early sales activities are part of DPD theory, their importance in wish/want projects could be stressed even more. Sales activities should start early and be performed in parallel with development. In addition:

- To succeed, wish/want projects must have advocates or sponsors in the organization (section 7.3.5 General PD findings).

An important aspect was found to be the control structure, figure 7.2. The control structure of DPD is more developed and stronger than that of common stage-and-gate methods, making DPD more controllable and more able to change directions swiftly. It was found that by stressing reporting even more, the control structure improves. Further, in DPD theory short term planning is stressed over long term planning that should be coarse. In the studied projects, it was found that:

- Timelines are just a snapshot of what is believed at the time when the plan is created, therefore to gain flexibility, time schedules should be substituted by reporting of results and an intense dialog (section 7.3.2 Planning).
- In a wish/want project, action plans are very useful (section 7.3.2 Planning).

Therefore, in case of wish/want projects, DPD theory would improve if the use of action planes were strongly stressed over timelines. Furthermore, it should be stressed that a project leader must be "master of his own house", meaning:

- In a wish/want project, in order to achieve high speed and efficiency, the project leader must have full authority over the project budget and other resources (section 7.3.2 Planning).

8.2. Outlook

Today we understand that aspects and occurrences that were considered insignificant, and therefore left out of earlier theories, may actually be the deciding factors (Goulielmos 2005). Simplification then, is not the way forward, but the complexity of the situation must be considered.

Organizations are complex systems, metaphorically seen as organisms that depend on internal systems of self-regulation, and adaptation to conditions, as they unfold. There are two central tools available for their study.

The first is complexity theory, which is increasingly well established in the natural and social sciences, but in PD literature only mentioned in a handful of articles, and then not to any depth.

The second is action research, in the tradition of Ottosson (1996, 2003) and Björk (2003). If more practitioners took up research in this tradition, then that would probably neutralize the dominant "detached and from above" viewpoint, as well as balance PD research away from an unfortunate bend towards quantification. Taken together, this would yield better and more useful theory.

If PD projects are organisms, then what do their nerve systems look like? How do they function? How should we bring a PD system to the edge of chaos? What should tools for dynamic strategies look like?

This thesis has addressed some questions, as a first step on the way. Many more deserve attention.

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Appendix 1 – The author's pre-knowledge

The author's formal education is given in figure X.1, nothing special there except maybe that the value of military training is often downplayed. The training of platoon commanders in the Swedish Army has probably been of great importance for the way Swedish males interact as managers at the workplace.

For the most part the author has been a consultant, but whether self-employed consultant or employee he has observed, oriented to, influenced and been influenced by the organizations that he has worked with, thereby gaining knowledge and understanding.

Companies and organizations that the author has either been employed at or worked with as a consultant include: ABB Motors AB, Astra Tech AB, Autoliv AB, Autoliv Hammarverken AB, Autoliv Mekan AB, Bertrandt Sweden AB, BITS AB, Bogma Maskin AB, Braathens SAFE, Chalmers Industriteknik, Chalmers Uddevalla Project, Chalmers University of Technology, Claes Johansson AB, Designer Nils J. Tvengsberg AS, Epsilon Development AB, Ericsson AB, Flygsfors Glasbruk AB, Frontec Research & Technology AB, Halmstad University, Hammarstedts Verkstads AB, Hasselblad AB, HAVD AB, Hymo AB, Hässleholm Automotive AB, Högskolan Trollhättan Uddevalla, Ingenjörshögskolan i Jönköping, Medical Robotics AB, Mekantransport AB, Morssing & Nycander Solicitors, Mölnlycke Mobility AB, NCC AB, Ostermans Aero, Plåtmekano i Vansbro AB, Prosolvia Research & Technology AB, Prosolvia Systems, PUC, SAAB Advanced Concept Center, SAAB Automobile AB, Scania AB, Securitas AB, SKF Nova AB, Stacke Hydraulik AB, Swedair Ltd, Svenska Flygverstäderna, Swepart Development AB, Tema Fritid AB, Torslanda Flygservice, Tradex Converting AB, TX Controls AB, UWAB, Verkstäderna Weibulls AB, VICI Industri AB, Visteon, Volvo Car Corporation, Volvo Truck AB, X-press AB.

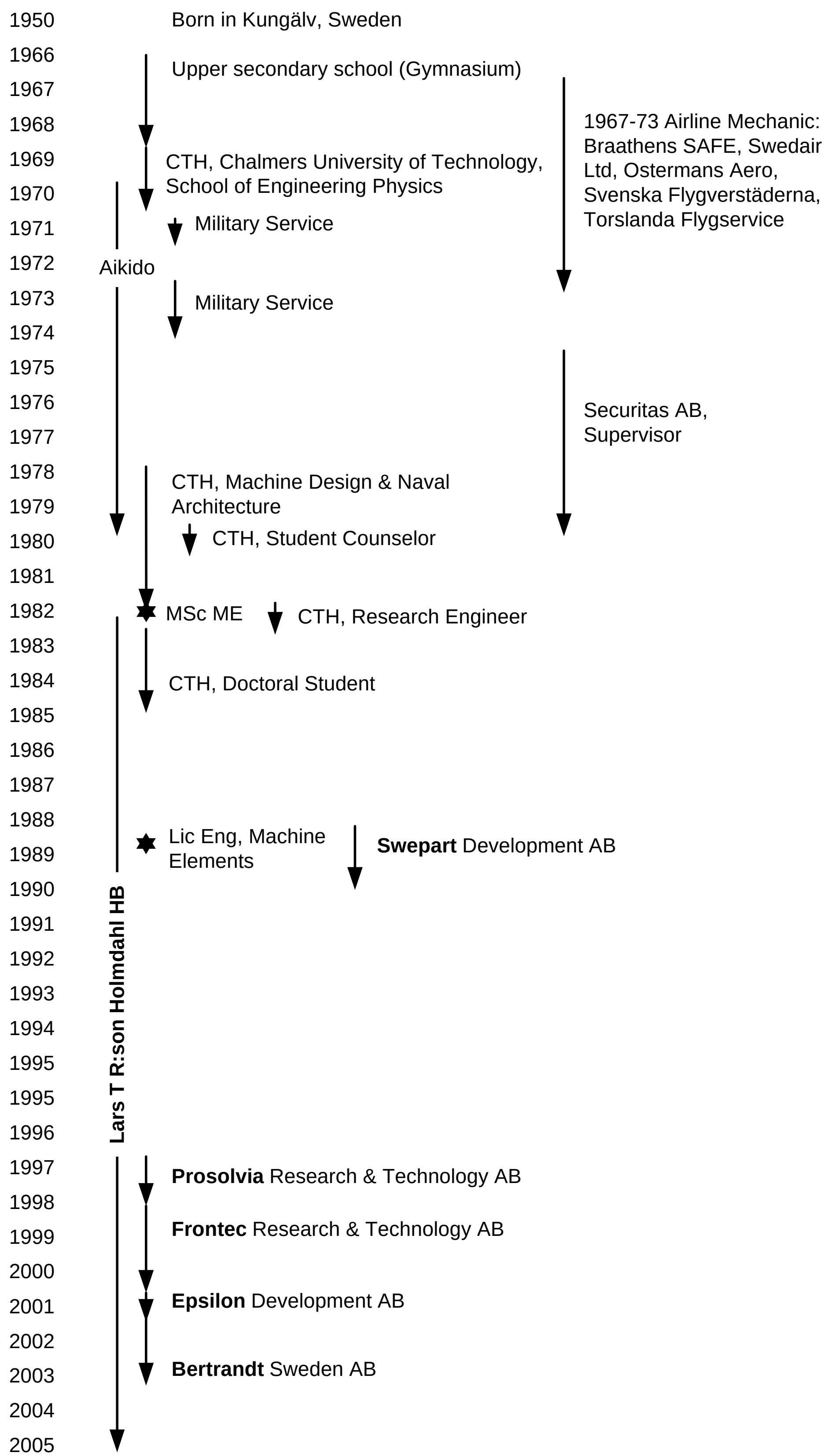


Figure X.1. A schematic description of education, employments, and other activities of interest

Appendix 2 – FRT offers a new service

FRT offers a new service

FEA/ CFD/ What ever—on demand

FEA, CFD, Stamping Simulation, Rigid Body Mechanics, Small Vibrations, Machine Elements Dimensioning, Machine Dynamics

Concerns firstly design engineers / project leaders in large and mid sized companies. In smaller companies, there probably is a greater need for someone that can take on a more general responsibility.

Target group

FEA- customers that require fast approximate answers to their questions in order to get on with their work.

Background

During new product development one often wants approximate answers to questions like: where is the highest stress, vibration frequency, and elastic deformation.

Midsized (and small) companies do not have the resources needed fro keeping expensive software and experts.

It is too expensive to purchase the service from consultants companies. The initial cost is too large for anyone to buy and try.

It is to slow a process to buy the service from consultants companies.

(We perform unnecessarily high precision. We put in to much work in non-value adding activities such as writing reports. We can rationalize or mode of working = create a better method).

Threats

There will come simple, low cost, FEA-software and the educational level is increasing.

1. Many think that they can manage without help.
2. Local consultants companies will enter the mechanical analysis business.
3. Those that get the small problems now, will later get the larger ones.

Reporting results

Long printed reports are not needed.

Communication by email.

Speak by phone.

Cash flow

Pay with card?

Almost no invoices (simple invoices) will lower cost. Low sales cost.

In data

Fill in a form on a web page.

Mail or email files to us, IGES, VDAFS, STEP, Catexp, or such, and then we analyze and mail back the result.

To sort out

How to manage document handling? How to draw and describe with words on the analysis plots?

Appendix 3 – Blanketten

”Blanketten” is Swedish for ”the form”, and is a structuring attempt of in data at this early stage in the project.

Blanketten

Legend: g = will be generated, i = to be filled in, f = preprinted.

		In data	**Comment**
1	g	ID, identify customer + assignment, organization no + serial no	
2	g	Datum (automatically)	
3	i	Customers name, tel, fax, email, Company, address, org no, Project name, -no, -mark	
4	f	FRT, address, org no, value added tax no	
5	f	Conditions: payment conditions	
6	f	Guaranty: given in data and limitations	
7	f	Additional services	
8	i	Type of service: Solving linear elastic problem Non linear problem (contact FRT)	
9	f	Strength: Risk for plastic deformation or failure Fatigue risk	
		Stiffness Displacement Spring rates (Functional demands regarding displacements)	
		Stability Buckling load and modes	
		Dynamics Resonance frequencies and modes Response analysis: stress- and motion (Functional demands: sound, fatigue, precision)	Quantitative Qualitative
		Heat flow Temperature field	
10	i	Material data, condition: norm, name, fabricated by	
11	i	What shall the result be used for? What exists today?	
12	i	Geometry information CAD, Pro/E, IDEAS, IGES, others Drawing Sketch/ picture/ description	
13	i	Load Size, distribution, position, direction and time dependence is shown in the CAD model, drawing or sketch	Coupled to chosen service
14	i	EC, BC, limitation, surrounding environment Is shown in special CAD model, drawing or sketch Description in words	Coupled to chosen service
15	i	Additional info	
16	i	Results elected	Coupled to chosen service

		Out data Sort Position (given in issue 14) Time Form Table (multiple choices, drop down menus) Graph (multiple choices, drop down menus) ISO plot Animation	
17		**Interpretation of customer data** Filled in correctly — receipt to customer Filled in incorrectly — contct customer fill in together	
		Check: geom., load, EC, BC, mtrl, others	
		Choose Method of analysis Analysis tool Level of ambition Precision of the results Describe chosen results Format, sort Positions Time points Number of plots Limitations	
18		Quotation	
		Formal issues	
		Type of service	
		Geometry, load, EC, BC, mtrl, others	
		Simplifications	
		Precision of different results	
		Description of results data (amount. format)	
		Opinion: judgment/conclusions regarding results	
		Suggested actions	
		Delivery time, under given conditions	
		Price	
		Order	
		Order accepted	
		Results	

Appendix 4 – Snabba Skott

”Snabba Skott”

A New Mechanical Analysis Service

An Internal Product Development

by

tekn. dr. Hans Bjarnehed, mech analysis

tekn. lic. Lars Holmdahl, mech design

Summary

The described service/method will correctly implemented yield

- Increased turnover
- Increased profit through higher invoiced amount per worked hour
- New customers
- Enhanced service to present customers
- Faster invoicing
- Less administration
- A substantial competitive advantage since we will become sole suppliers at a new market

Release 10

Contents

(Middle column numbers indicate page numbers in original report)

”Snabba skott”

Snabba skott (Quick shots) has got its name from the demand from product development for quicker answers, results, from the mechanical analysis department.

Snabba skott is web based and designed for use of modern efficient communication methods. As much as possible of the administrative work is automatically handled.

Communication with the customer is done by email and by telephone.

Adjustment to the design process

Our product is a web-base analysis service that provides the ability for ”quick shots”. By this we mean support to the design engineer early in the process where no one is active today providing services.

Design engineers are constantly faced with problems like:

How much good would reinforcements like flanges and ribs do, is it worth the cost?

1. This is an area with intense load, but how much does it hurt?
2. Whar are the natural frequences for the four alternatives?
3. Where can I safely remove material?

These and similar questions demand quick answers because they are asked daily in the early design phases, during concept design and start of detail design.

Traditionally mechanical analysis services have been used, not for development, but for verification. This is due to several causes

1. Too high a threshold (minimum one week and 30 000 SEK)
2. Our quotation process with to many non-productive activities
3. Difficulties in the communication between design engineers and mechanical analysts.

We will change this with our new service/product.

When this new way of working has gained acceptance it will force out the old work method.

The present, traditional, work methods use of time is shown in the figure 1. The new web-based work methods use of time is shown in figure 2 on the next page.

	1	2		3	4	5	
O/K qoute communicate	**M** model	**M**	**A** analys	**P** post-process	**R** report	**R**	**K/Ark** Communicate & archive

Figure 1. The present, traditional, work method.

The traditional work method comprises at least 5 days and costs 30 000 SEK as a fixed price job. There will in practice always be added an additional day before and after the job for quotation work, communication with the customer and for archiving documents and files, turning this into a 7 day job.

Revenue per day 30000 / 7 = 4 333 SEK

1		2		3	
T **O**	**M** model	**M**	**A**	**A** analys	**P** **R**

Legend
T = interpret, O = quote
M = model, A = analyze
P = post process
R = report

Figure 2. New, web-based work method.

The new method comprises only 3 days (against earlier 7) and will cost 20 000 — 30 000 SEK as a fixed price job.

Revenue per day 30000 / 3 = 10 000 SEK, or 20 000/ 3 = 6 667 SEK.

Thus we can lower the cost for the customer, raise our hourly rate (we do not tell the customer how many hours we work) and shorten delivery time. This work method is applicable to all assignments, but the profit will greatest for short jobs.

Market size for mechancal analysis jobs of 0,1-1 weeks, has been estimated to circa 100 MSEK in addition to the present market for 1-8 week jobs of circa 180 MSEK.

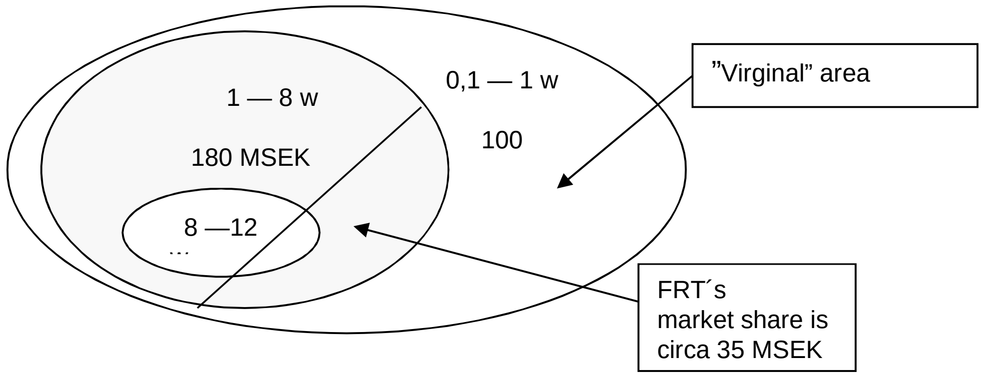


Figure 3. Beräkningstjänster utförda på kontoret. Den svenska marknadens storlek.

”An ounce of prepare is worth a pound of repair”

FRT analysis department will meet tougher and **increased competition** from primarily two directions.

1. Among **our customers** the competence level is increasing and soon ever more of them will have at least one employee who is skilled in strength of materials and finds pleasure in fiddling with FEA. Also FEA software will be ever more affordable and more competent. This combination will remove from us the simpler cases/jobs. With time this process will remove the difficult cases from us also.
2. **The local consultant** (small firms) will employ persons who are trained in FEA. This combined with low cost software will lead to increased local supply of FEA services. Low rates and local presence will force us out of the market for simpler jobs first and then for the more difficult ones later.

We will meet the competition by removeing or forcefully reduce all non-productive- and non-specialist work, which in the case of mechanical analysis are

1. Quotation work
2. Start-up meetings
3. Report writing
4. Oral presentations
5. Customer visits
6. Communication regarding technical prerequisites and results.

In this way we will be able to offer low price and yet earn very high hourly rates. We will gain high profitability and a competitive price level. The same specialists, software and computers that simulate car crashes for the automobile companies will be available to the mid sized companies and their design engineers. This is something that our competitors can’t match.

Our strength

- Safety; the customer knows beforehand exactly what he will get for his money.
- Easy to understand and simple purchase.
- Easy to understand and simple results presentation.
- Quick response.
- Low competitive price.
- 24/7 presence
- The best specialists
- The most competent (and expencive) softwares
- The best computers

Plus services

The standard service is lean and optimized. In case customers want services in beyond the standard level we will supply so-called plus services.

1. Oral presentation
2. Written report
3. VRML-file (plott resultat)
4. Animations
5. CAD
    - Converting of non-standard formats
    - Engineering design
    - Geometry from a drawing
6. Optimization of design
7. New or extended job of non-standard character
8. Evaluation at customer' site

The advantage with this is that we will be paid for all our work.
Today it often happens that we don't invoiced the customer until the customer thinks the job is finished. Since we almost never specify necessary conditions for the job to be finished, the shrewd customer can, if he so wishes, extend a job far beyond what the sales person had intended.

Action plan

The following remains to be done in order to create the new service. Estimated time needed at each level, in workweeks, is given in within brackets at each activity.

1. Skylten ”The sign” (is worked on as we go) (2w)
    - For every service develop examples of different types of assignments (2w)
        - Decide what to emphasize (what should the example show?)
            - Plots, graphs, tabels, resolution
            - In put, result, format
2. Shoppen ”The shop” (1,4w)
    - Encryption
        - Investigate if/when that is needed (0,2w)
        - Decide how to do it
    - In/out data format
        - Investigate what is used today (0,2w)
        - Decide what we should be able to handle
    - Develop definitions with examples (loads and BC) for in put support (1w)
3. Work method (6,8w)
    - Customer interaction (4,5w)
        - Develop ”blanketten” (the in data form) (2w)
            - Develop a report template (2w)
        - Elect editor for putting in CAD, email, fax into ”blanketten” (0,4w)
        - Investigate/decide what different file format we shall support (0,1w)
    - Load description (0,8w)
        - Develop definitions and examples of load descriptions (0,8w)
    - Interpritation (0,5w)
        - Develop policy for election of analysis tools (0,2w)
        - Develop policy for election of resolution(0,3w)
            - Engage students for examination thesis work
    - Quote (0,2w)
        - Decide policy for deciding delivery times
        - Decide policy for pricing
            - Who sets the price and with what policy?
    - Results (0,2w)
        - Decide what editors that should be used for the results printout (0,1w)
        - Decide what special file formats to support (0,1w)
    - Archiveing (0,2w)
        - Decide what to archive
        - Decide how to do it
    - Time follow up (0,2w)
        - Investigate how to
    - Payment (0,2w)
        - Decide how the job is reported to the economics department
        - Decide how the job is invoiced
4. Work through one case (2,4w)
    - Select problem (0,1w)
        - Select geometry and loads
    - Test different file formats for data transfer (0,2w)

Test file format transformations (0,2w)
Select analysis tool & resolution (investigate influence of solve time) (0,8w)
Test methods for to comment on results plots (0,6w)
Test methods for results transfer to customer (0,4w)
Test methods for economy reporting and invoicing (0,1w)

5. Web site (7w)
    - Develop logical web structure (1w)
    - Programming & styling in cooperation with other Frontec company (6w)
        - Programming
        - Graphical design
6. Market introduction (10w)
    - Select three customers with whom to refine the product (3w)
    - Demo work method for customers when the product is finished (4w)
    - Develop marketing (2w)
        - Select forums and media
        - Design the message
    - Kick-off seminar in Jönköping August 2. `99 (1w)

Time plan is shown in the figure on next page

Cost

The cost for product development is divided between work and investment.

Work

Time used

Project management[1]	18,0w,	216 000 SEK
Skylten, ”The sign”	2,0 w,	48 000 SEK
Shoppen, “The shop”	1,4 w,	33 600 SEK
Work method	6,8 w,	163 200 SEK
Work through one case	2,4 w,	57 600 SEK
Website	7,0 w,	168 000 SEK
Market introduction	10,0 w,	240 000 SEK
Sum	29,6 w,	926 400 SEK

1/ Project management 50% of full time

Cost based on 40h/week and 600 SEK/h.

Investment

Telephone line, modem, PC, fax software, MS Office,
scanner, digitizer tablet, mouse pen 30 000 SEK

Sum total 926 400 + 30 000 ≈ **960 000 SEK**

Marketing strengths

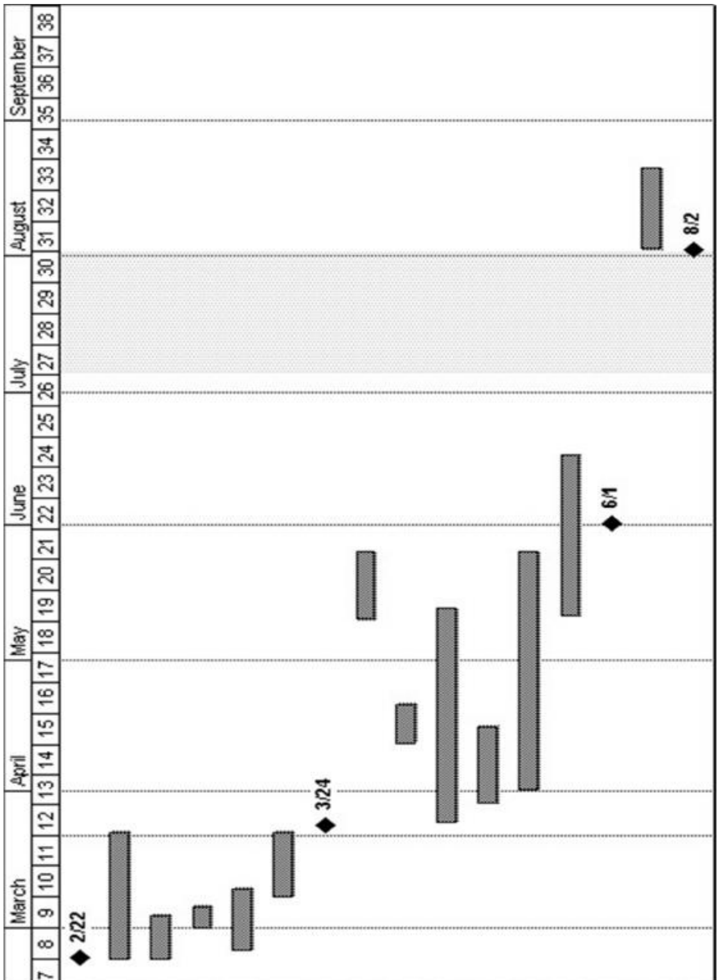
The following signal words or entities describe the product or the feel that we want to convey.

1. Fast, efficient (the right resolution), cost effective
2. Safe, wee guarantee the result. Quality of deliverance (delivery time, the right level of ambition)
3. Simple, clear and unambiguous, easy to use.
4. Design engineer support, elite competence, professional results.
5. Modern, web, methods & tools = state of the art, best practice

The target group is present customers plus other large and mid size companies.

Time plan

ID	Task Name	Duration	Start	Finish
1	Starta proj	0 w	Feb 22 '99	Feb 22 '99
2	Rapporten	4.2 w	Feb 22 '99	Mar 22 '99
3	Logisk struktur	1.6 w	Feb 22 '99	Mar 3 '99
4	Marknad	1 w	Mar 1 '99	Mar 5 '99
5	Web-layout	2 w	Feb 24 '99	Mar 9 '99
6	Handlingsplan	2.2 w	Mar 8 '99	Mar 22 '99
7	Styrelsemöte	0 w	Mar 24 '99	Mar 24 '99
8	Skylten	2 w	May 10 '99	May 25 '99
9	Shoppen	1.4 w	Apr 12 '99	Apr 20 '99
10	Arbetssättet	6.6 w	Mar 25 '99	May 12 '99
11	Case	2.4 w	Mar 29 '99	Apr 15 '99
12	Websajten	7 w	Apr 1 '99	May 25 '99
13	Marknadsintro 1	5 w	May 11 '99	Jun 16 '99
14	Lansering	0 w	Jun 1 '99	Jun 1 '99
15	Marknadsintro 2	3 w	Aug 2 '99	Aug 20 '99
16	Kick-off seminar	0 w	Aug 2 '99	Aug 2 '99



Figur 2. Time plan for the product development of “Snabba Skott”.

Data transfer between customer's software and FRT-software

Customer			FRT					
Geometry and loads			Analysis software			Editor		
Carrier	Format	Note	In data		Out data	In data		Out data
Electronic	pro/E, IGES, STEP, Catexp, DWG	3D	IGES, STEP, vda	I-deas	EPS, HPGL, gif, jpg, pcx, png,	ppt, pps, ch3, sh3, shw, cht, drw, pre, rtf, doc, wsd, txt, htm, html, htx	Power Point	ppt, wmf, rtf, pps, jpg, gif
	Dxf, HPGL, EPS, Tiff, Jpg	2D	IGES	I-deas/Abaqus	PS, gif, HPGL		X-view (unix)	
Paper	Drawing, sketch, picture		IGES	I-deas/Nastran	PS, gif, HPGL			
	Description	Description	Nastran, patram, universal, I-deas, m-series, free form, beta-tank, wave front, st-Lithgrp, fluent, LS-dyna	Ansa	EPS, HPGL, gif, jpg, pcx, png, IBMGL, Autocad slide			
Electronic	txt, doc	Description		Ansys				
				ProMechanica				
				Procision				
				Adams				
			dxf	Working Model	dxf, dta, avi, PS, HPGL, DDE			

Appendix 5 – Project budget as of week 16

The project budget as of week 16.

	"Pre study"								**Data base specification**					**Web programmig**			
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
Hans B, 450 SEK/h		4	4	2	3	2	2	3									
Lars H, 400	9	17	32	22	9	9	7	10	7	9	0	12	16	16	16	16	16
Marcus W, 300										2	15	25	24	32	32	32	32
Johan B, 300										6	14	38	32	40	40	40	40
FRT resorce, 300SEK/h														32	40	40	40
FRT resorce															32	40	40
Sum time	9	21	36	24	12	11	9	13	7	17	29	75	72	120	160	200	280
Accum time		30	66	90	102	113	122	135	142	159	188	263	335	455	615	815	1095
Cost [kSEK]	4	7	15	10	5	5	4	5	3	6	8	24	63	39	51	63	87
Accum cost		11	26	36	41	46	50	55	58	64	72	96	179	218	269	332	419
Interactive													60				
Interactive																	150
Marketing																	350
Server, etc														30			
Total accumu-lated		11	26	36	41	46	50	55	58	64	72	96	239	308	359	422	1009

	Launch				**Free**					**Re launch**			**Proj. end**	
	22	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**
Hans B	8	8	8						8	8	8			
Lars H	24	24	16	16						24	24	16	16	16
Marcus W	24	32	32	16										
Johan B	32	32	32	16										
FRT resorce	32	32	32							32	32			
FRT resorce	32													
Sum time [h]	152	128	120	48					8	64	64	16	16	16
Accum time	1247	1375	1495	1543					1551	1615	1679	1695	1711	1727
Cost time [kSEK]	49	42	39	16					4	22	22	6	6	6
Accum cost time	468	510	549	565				565	569	591	613	619	625	631
Interactiv[kSEK]				75										
Marketing				100								50		
Total	1058	1100	1139	1330	1330	1330	1330	1330	1334	1356	1378	1434	1440	1446

Appendix 6 – Profitability analysis

Arguments

"Snabba skott" is a new way of working. With "Snabba Skott" we create true COD, "calculations on demand", which means: the mechanical analysis service is made available whenever the design engineer asks for it. For the very first time we can effectively support the design engineer in a development project with numerical analysis. We make available a "tool" that no one else can provide (yet).

"Snabba skott" is a new business process. "Snabba Skott" will influence our whole way of working in all projects to larger or smaller extent. The mechanical analysis department gets a quick method for making short (and long) project profitable. The different local offices are given a possibility to increase their customer service. Our sales staff is given something new to sell.

Soft profitability factors. With soft factors I mean such factors that are difficult or impossible to measure. These factors are active not only within "Snabba Skott" but in all company activities.

The idea with "Snabba Skott" is to

- Quickly provide the customer with the results he asks for.
- Remove all unnecessary work (remove all waste)
- Automate as much work as possible
- Give an effective method for to specify, start and terminate jobs.
- Continues local presence.

Quality assurance. Follows from the fact that we have a thoroughly described process that we follow.

More customers. *This we believe* will happen as a result of all marketing activities we are planning to do.

More jobs. *This we believe* will happen as a result of all marketing activities we are planning to do.

Jobs of a new kind — synergy effects, plus services. We offer our customers so called plus services in "Snabba Skott" and we will get more jobs as a result of the marketing of "Snabba Skott".

Commercial value. By aid of correctly performed marketing customers will get a positive knowledge of FRT, which will be perceived as successful, energetic, competent and sympathetic. This will lead to better business.

We always have a cost for commercial activities whether we initiate "Snabba Skott" or not.

Better job control and guidance. This follows from our thoroughly described process that we follow. The concentration on "Snabba Skott" and the reduction of unnecessary manual labor, combined with automatic logging of work progress will yield a good guidance and control. The automatic handling of data will allow a very good collection of statistical data. Over time we will build a very good customer database.

Not based on hourly rates. Since pricing is in accordance with what the customer is willing to pay and not our use of resources there is a potential for a very good profitability.

The Nordic countries are our market. We achieve local presence in time and space. By this we mean that the customer always, at all times and wherever he is can place a request for quotation with us. We can by working days and night, truly 24/7, and putting out solutions on the customers own project page in "Snabba Skott" provide the customer with solutions very, very fast.

Facilitates "looping". Since the customer in an efficient way can refer to earlier jobs placed with us, we can reuse earlier results. This will shorten cycle time even more and allow for an efficient iterative work method.

Even large, long, assignments. There is nothing to hinder the performance of large jobs through "Snabba Skott".

Snabba Skott will be extended with other packaged services. With time we will add additional services. For each new service we will have a natural cause for communicating with the market.

Appendix 7 – Market research

The results of simple market research were promising.

Project no	Company	Commentaries
15041	Autoflator AB	Björn Olsson: *Interesting alternative, good to shorten time*
15071	Nordbergs Mill AB	Rolf Ericsson*: Very good – smart, I'll buy!*
15151	SAAB Automobile AB	Karin Borg: *Nothing for us now because it does not allow competition.* *After some explanation about explorative analysis versus verification she became somewhat apprehensive.*
15161	JMS Systemhydraulik AB	Karl-Magnus Wireskog: *Completely right!*
15201	Autoliv Sweden AB	Gunnar Helmgren: *Good complement to the methods of today*.
15371	Ericsson SAAB Avionics.	Mats Hult: *Interesting but we work under secrecy. Can probably suite some of our needs.*
	Autoliv Hammarverken AB	Development manager Jan Odenmo: *Wonderful!*
15401	Tetra Pak R&D AB	Bo Runnberg: *Sounds interesting, but we do not have Internet access on our workstations so then I'll have to sit at another computer.*

Appendix 8 – Document from meeting 1999-06-10

The responsibility areas were simply defined as: *the project organization (hierarchical plan) roughly defines areas of responsibility. Each project member is responsible for carrying out, in the best way possible, those work units that he/she has accepted.*

Communication and data structure. On the FRT net server there is as usual a project folder. The structure is as follows.

(the data structure given in the original document is omitted in order to save space)

Communication & reporting shall be as follows.

Daily all FRT project members will write what he/she has done during the day in an activity report file under \project_spec.

Weekly the project leader reports to the project sponsor.

Weekly project meetings are for making decisions on the following steps to take, but may occasionally also be used for reporting.

Documents: all documents must have a date and an issue-number.

All decisions must be documented.

Then followed a description (excluded here) of what results were expected from respectively market, interface/work method, and coding.

The following part, the strategy and time plan is given in its entirety because they are of fundamental importance.

Execution

The execution builds on the results of the project so far, the so-called pre study. Especially the work method has been specified in the document concerning the "indatablankett". A number of help texts have been written. Data flow has been described in two schemas. See \mechdesign\pågående\1999\9009 Snabba Skott\ .

Strategy

The creation of COD is to be carried out in accordance with the DPD-model, which stands for "Dynamic Product Development" (professor Stig Ottosson).

The principle of the work is the time-box, which means that the time frame is fixed but the content is adjusted thereafter.

DPD means that you do in every instant that which is possible to do regardless of what category that work unit belongs to. In this way activities are compressed and the shortest possible development time is achieved.

The time-box principle is an efficient way of working, where there is no time for waste and time spans are so short that one does not forget.

That which is considered as of less importance (not necessary fo a bare-bone application) is saved for later.

Time plan

The time plan is given in two ways; one general overview with only sub goals, and one more detailed for a shorter time span, see appendix.

General overview time plan

w24: Work method frozen and database described.
w26: Web pages and database coded.
w32: One case worked through.
w33: User tests carried out.
w35: Launch and company internal information meeting.
(w43: Presentation at the Technology Fair in Älvsjö 23-28th of October).

Appendix 9 – COD press release

The press release that was sent out together with printed material and diskettes with COD files.

FRONTEC

Press release 1999-10-12

COD – a new business on the Internet

Technical support to fast product development

Frontec Research & Technology launches COD (Calculations On Demand), a completely new business on the Internet targeting foremost product developing companies. With COD you get fast, reliable and cost efficient mechanical analysis support in your product development. COD yields shorter lead-time and allows for a more iterative and resource lean process.

Technical calculations (strength of materials, fluid dynamics, heat flow, etc) are not used are not used as much as they should. The reason can be lacking capacity in the large enterprise and a prohibiting cost for the small business. With COD, Frontec wants to cure all this. Through COD the small company gets fast and without fuzz, cost effective access to the same specialists that for instance perform whole body crash simulations for the large automobile manufactures, and the large company can get a much needed relief from a pressing workload.

The speed is a quality in itself that allows a completely new way of working. Now you no longer need to save simulations to the end of the project where they mainly serve as a final numerical verification. With COD it is possible to dimension with precision at every uncertain design point instead of over-designing. Thereby risks are reduced in the project and one gets a faster more resource efficient product development.

– Every time, everywhere, is the thought behind COD. At the precise moment that a design engineer needs a mechanical analysis result he should have it. With COD, our new business on the Internet, this has for the first time become possible, says Lars Holmdahl, project leader of Frontec Research & Technology. We believe that in the future COD, will become the dominant way for providing analysis services.

Web based

The user enters www.cod.nu, fills in the form where the problem is described. A so-called COD-pilot receives the request, interprets it and emails back a quotation that contains price, delivery time, and results description. When the quotation is accepted the problem solving starts.

The result, with the specialists comments, is publicized on the customers user page on the COD website. Any inconsistencies are clarified directly with the analyst that has performed the mechanical analysis.

Cost is kept to a minimum because all non value-adding activities have been performed automatically.

For more information please visit www.cod.nu or contact:

Lars Holmdahl, Frontec
Tel: 031-707 10 00 • 0709-76 77 79
e-mail: lars.holmdahl@frt.frontec.se

Markus Wallentin
Tel 031-707 65 22
e-mail: markus.wallentin@frt.frontec.se

About Frontec

Frontec is a Swedish consultants company within IT, management, product- and software development noted on the Stockholm stock exchange O-list. Frontec has local offices all over Sweden and is active within two fields: IT (among others specialists in e-commerce and systems integration) and Technology (expert competence within product- and production development). The business idea is to shorten lead times and to rationalize customers' business processes and projects. Customers are mostly found among the Nordic 500 largest companies and organizations within telecom, manufacturing industry, public service, commerce and transport.

The subsidiary *Frontec Research & Technology AB* has ca 130 employees, 75% MSc or higher, every seventh has a research education, and provides services within all phases of the design process.

Appendix 10 – A small survey

By using ELSEVIER SCIENCE @ DIRECT: FULL-TEXT(questionnaire) and FULL-TEXT(product development process) and response and survey, a total of 72 articles were found for the period 2000.01 – 2005.07 of which 44 were relevant and further reduced to 40 because of ambiguousness in the articles that were removed.

Reference	Single respondent	Multiple respond.	Pre-tested / pilot	Targets initially contacted / selected	Targets finally selected	Response rate [%]	Call to find informant	Call for agreement	Pre-notification	Drop-off-and -collect	1st letter	Reminder call	2nd letter / postcard	3rd letter	Fax	Email	Note
March-Chorda et al 2002		1--2			65	100											personal interviews
Wren et al 2000		2			375	100											personal interviews
Gemser & Leeders 2001	y				47	100	y	y									personal interviews
Walter 2003	y			567	267	93	y	y									personal interviews
McIvor & Humphreys 2004	y			600	45	89					y						Questionnaire combined with case studies
Nakata et al 2005	y		y		319	81	y	y		y	y	y			y		81% combined value of Korea 93% & Japan 69%
Hyvättinen 2006		2			18	80										y	interview first then questionnaire was emailed
Davila 2003	y		y		73	77					y						Gift to respondents: article + results of survey
Maltz et al 2001		ca 4			1061	74					y		y				Boss pointed out respondent
De Brentani 2001	y		y		184	67	y	y			y						
Bengtsson & Sölvell 2004	y				234	62					y		y				
Nijssen & Frambach 2000	y		y		125	60	y	y									telephone questionnaire
Sethi & Nicholson 2001	y				240	59	y	y			y		y				
Yam et al 2004		ca 5	y		375	57											
Römer et al 2001	y				200	53											respondents received a book as a gift
Kim et al 2005	y				250	48	y	y	y	y							
Varela & Benito 2005	y		y		159	47		y			y				y	y	personal
Dröge et al 2000	y				57	39	y	y			y	y					Boss pointed out respondent
Carbonell-Foulquié & Munuera-Alemán 2004	y			957	200	38		y			y						1st letter to 957, then tel. to 400 of which 200 did no PD, yields ca 200 firms of which 77 answered (38%)
Fynes et al 2005	y				538	38					y			y			
Cristiano et al 2000	y				800	37					y		y				800 business units
Harmsen et al 2000	y		y		1410	37					y		y	y			two reminders
Fynes & Búrca 2005	y				1003	35					y						
Swink 2003	y				1362	34			y		y		y				no correction for poor data base yields approx 10%
Akgün et al 2005	y			150	80	34	y	y									
Lu & Yang 2004	y	ca 4			151	28				y	y	y				y	Boss pointed out respondent
González & Palacios 2002	y			363	195	28	y	y			y	y	y				
Lüthje 2004			y		620	26					y		y				consumer survey
Sánchez & Pérez 2003	y				249	25											Reference talks of having a "follow up process"
Driva et al 2000	y				580	24											combined qualitative/quantitative methods
Stump et al 2002	y		y	1500	1485	22					y		y	y			Respondents were promised executive summary
LaBahn & Krapfel 2000	y		y	2550	1972	21	y				y		y	y			3rd letter a shortened questionnaire
Leenders & Wierenga 2002	y			1000	789	19					y		y				Due poor data, effective sample smaller
Kahn 2001		ca 3			300	17					y		y	y			
Pujari et al 2003	y				1000	15					y						
Frambach et al 2003	y		y		1500	13					y	y					
Koufteros et al 2002	y				2500	10					y						
Narasimhan & Nair 2005	y		y		4500	9					y		y	y			
Li et al 2005	y		y		3137	6,3					y		y	y			web version available
Petersen et al 2005	y			3000	225	2,7			y		y				y		1st mail & fax response was 4,5%, from those response in next step was 60% yielding a total rate of 2,7%

Table 10.1. Result of survey. Legend: y = yes.

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Figure 0.1. The Pareto principle

Appendix 11 – The author's CV

1950.03.21	Born in Kungälv, Sweden, as son of engineer Roland Holmdahl and his wife Britt-Stina Holmdahl, born Yngveson.
1957-1963	Attended elementary school (folkskola) in Fåglavik and Flygsfors, Sweden.
1963-1966	Attended secondary school (realskola) at Paradisskolan in Nybro, Sweden.
1966-1969	Attended high school (gymnasium) at Paradisskolan in Nybro, Lundby Gymnasium and Polhemsgymnasiet in Gothenburg, Sweden .
1967-1973	Employed part time as airline line-maintenance mechanic at Braathens SAFE, Swedair Ltd, Ostermans Aero, Svenska Flygverstäderna, and Torslanda Flygservice.
1969-1971	Studies at Chalmers University of Technology, School of Engineering Physics.
1971	Military service, Preparatory Platoon Commander School, I21, Sollefteå, Sweden.
1973-1974	Military service, Platoon Commander School, I21, Sollefteå.
1975-1980	Employed as supervisor at Securitas AB in Gothenburg.
1978	Resumed studies at Chalmers University of Technology (CTH)
1980-1981	Student counselor for 10 month, School of Mechanical Engineering and Naval Architechture, CTH.
1982.05.07	M Sc ME exam from School of Mechanical Engineering and Naval Architecture, CTH
1982	Employed as research engineer for two month at School of Mechanical Engineering and Naval Architecture, Division of Machine Elements, CTH.
1982-1985	Doctoral student at School of Mechanical Engineering and Naval Architecture, Division of Machine Elements, CTH.
1989.09.29	Licentiate of Engineering exam (machine elements), CTH.
1982-1990	Self employed consultant through Lars T R:son Holmdahl HB, assisting clients with NPD; feasibility studies, engineering design, development of: theory, mechanical analysis software, and test methodology, resulting in new business for the clients, novel design solutions, patents (machine elements), and new scientific theory (tribology).
1990-1991	Employed at Swepart Development AB, as Manager of Technology with responsibility for managing NPD projects, and recruitment of employees. Member of the management team.
1992 -1997	Self employed consultant through Lars T R:son Holmdahl HB, assisting clients in foremost automotive industry with management of NPD projects, and product- & business development.
1997 -1998	Employed at Prosolvia Research & Technology AB (PRT) as Project Manager.
1999-2001	Employed at Frontec Research & Technology AB (FRT) (FRT had acquired PRT), as Senior Project Manager, additionally with responsibility for recruiting and competence development of employees. Member of the management team.
2001	Employed as Senior Project Manager with Epsilon Development AB, which had acquired FRT. Occupation was mainly strategy work.
2001-2003	Employed with Bertrandt Sweden AB, as Project Manager with responsibility for project coordination, - budgeting, -controlling, acquisition of assignments, recruiting, project leadership, and method and competence development. Member of the management team.
2003-	Self employed consultant through Lars T R:son Holmdahl HB, lecturing on product development at the colleges of Halmstad, and Trollhättan Uddevalla, Sweden, and training of industry project managers and sponsor teams. Finalized the Dr.-Ing thesis.