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Innovation at Large

Managing Multi-Organization, Multi-Team Projects

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1 Introduction

1.1 Increasing Complexity in New Product Development

In new product development (NPD) the complexity of new products is continuously increasing (Hoegl and Weinkauf, 2005; McDonough et al., 2001; Wheelwright and Clark, 1992). This can be best illustrated by the history of high-tech products, whose successful development is the focus of this research.

Looking back a century, for instance, automobiles and aircrafts were much less complex than today. At the time of their invention these products were made of a small number of components that could be constructed by only a few individuals who had the necessary expertise and resources to complete the entire product (e.g., the 'Motorwagen' (motor vehicle) by Karl Benz in 1885, and the 'Stahlradwagen' (steel wheel automobile) by Gottlieb Daimler and Wilhelm Maybach in 1889; or the glider by Otto Lilienthal in 1891, and the first successful powered aircraft by the Wright Brothers in 1903) (Inventors, 2006; Aviation-history, 2006). Nowadays, even their many different functional parts (e.g., engine, electronic, and hydraulic systems) are so complex that they can no longer be developed by just a few individuals.

Complexity in NPD can be defined by three main elements: (1) the number of functional components/tasks, (2) the difficulty/newness of the tasks, and (3) the intensity of interdependence between the functional components/areas (Kim and Wilemon, 2003; Novak and Eppinger, 2001).

Complex new products are increasingly developed in very large NPD projects, comprising hundreds to thousands of persons in numerous teams. This collaborative team structure derives from the product's architecture (Sosa et al., 2004; Von Hippel, 1990). Each team is responsible for a certain (part of the) product's component(s). They are formed to integrate the various functional skills and expertise needed for performing the assigned complex design tasks (Hoegl and Gemuenden, 2001). This multi-team (MT) approach allows for highly specialized designing within teams with a certain degree of independence from other teams.

However, the diverse knowledge that is required often cannot be found within a single organization. The same applies to the different technologies and resources that are necessary. Because of the highly complex state-of-the-art technology, individuals and organizations are becoming more specialized (Bensaou and Venkatraman, 1995). This means different organizations need to collaborate in the NPD process leading to a multi-organization (MO) approach.

The development of complex new products, hence, requires diverse competencies and resources that often exceed the capacity of a single team (Hoegl et al., 2004) and strain even the largest firms (Kazanjian et al., 2000; Singh, 1997). Because of the increasing product complexity, multi-organization (MO), multi-team (MT) (i.e., MOMT) projects are becoming more common in NPD practice and will be increasingly encountered. As O'Sullivan (2003) states, they can be found in different fields developing products characterized by large scale, technological complexity and long duration. Advanced information- and communication technology supports this process (Dodgson, 1992; Premkumar et al., 2005) since for complex NPD the required dispersed expertise can be accessed and connected easily. Figure 1.1 gives examples of MOMT projects that have been established, mostly in recent years, to develop complex new products.

In this research MOMT projects are considered as being complex themselves since numerous members of diverse functions from different organizations, also located in different countries, cooperate in many teams to jointly develop a complex new product. In collaborative work they can profit from the synergetic effects of the combination of expertise and resources (Harvey and Koubek, 2000; Mintzberg et al., 1996; Saavedra et al., 1993; Singh, 1997) and can reduce high costs and risks in order to be more competitive (Dodgson, 1992).

However, MOMT projects are very challenging. To deliver insight into the challenges of these projects, an example of the ***aircraft industry***, namely the development of the Airbus A380 – with 555 seats on two decks the world-biggest and most complex passenger jet ever built, is given in more detail.[1] In December 2000, Airbus (daughter of EADS) voted to build the A3XX, renamed as the A380 with estimated costs of about 10bn euros. The prime contractors are France, Germany, UK, and Spain; and the industrial partners are Australia, Austria, Belgium, Finland, Italy, Japan, South Korea, Malaysia, The Netherlands, Sweden, Switzerland, and USA (Airliners, 2006). In France, within many different teams, the center wing box, center fuselage, nose section and radome are developed. In Germany the aft and forward fuselage and vertical tail plane, in Spain the tail planes and central belly fairing, and in the UK the wings are developed. All parts are assembled in Toulouse, France. (BBC Southern Counties, 2004)

During the development of the super-jumbo there were several delays, for instance, due to massive wiring problems (BBC business, 2006; Parker, 2006). Each plane needs 500 kilometers of wiring in the sections of the fuselage. Because of a lack of communication – not recognizing the relevance of decisions

[1] Please note: if not indicated differently, the case description is based on BBC business news (http://news.bbc.co.uk/1/hi/business). More precise addresses accessed from this website are provided in the reference list.

Computer technology: e.g., Fujitsu Limited (Japan) and Siemens AG (Germany) founded Fujitsu Siemens Computers (Holding) B.V. in October 1999 to 'synergize innovative drive and strengths', working in different specialized teams like information technology and information system, customer support, services, and marketing (Fujitsu-Siemens, 2006). However, there is still a high market uncertainty not only because of competition, like Hewlett-Packard's takeover of Compaq in 2001, but also because of falling computer demands (BBC Business, 2001).

Automotive industry: e.g., the BMW Group, DaimlerChrysler (both Germany), and General Motors (USA) jointly develop a two-mode hybrid drive system they each want to apply in their individual vehicles. In September 2005 they signed a "memorandum of understanding" to 'pool the development expertise' and 'integrate best technologies on the market', working in highly specialized teams on the design and development of the different parts of the hybrid drive system (General Motors, 2006). They planned to unveil the hybrid drive system the end of 2007, with a cost of $1 billion. Competitor Toyota has already successfully introduced the hybrid in 1997 and improved further since then (Weber, 2006).

Public transport infrastructure: e.g., the Channel Tunnel that connects France and the UK was a joint construction of both countries that had started in 1988. The Channel Tunnel officially opened in 1994. Construction problems arose because the construction teams were working virtually independently on each side of the channel. There was a construction cost overrun of fixed prices of 80 percent (Flyvbjerg et al., 2003). Besides the exceeded construction costs there was also a delayed operation and the ticket sales of the train service were disappointing (Grün, 2004).

Energy transport infrastructure: e.g., the Baku-Tblisi-Ceyhan (BTC) pipeline from Azerbaijan via Georgia to Turkey – the second longest oil pipeline in the world – was commissioned by a consortium of energy companies led by BP (UK), with the members AzBTC (Azerbaijan), Chevron (USA), Statoil (Norway), TPAO (Turkey), Eni (Italy), Total (France), Itochu (Japan), INPEX (Japan), ConocoPhillips (USA), and Amerada Hess (USA). Different teams for, for instance, consultation, land acquisition and community, and construction, collaborated. The construction began in September 2002, and the pipeline was officially inaugurated on July 13, 2006; more than one year behind schedule (Chossudovsky, 2006). The construction costs were 30 percent above the original estimate ($3.9bn instead of $2.95bn) (Alexander's Gas and Oil Connection, 2006).

Cooperation in non-profit sector**:** e.g., the European alliance for motorists 'ARC Transistance', founded in 1991, is a cooperation of the 8 major European automobile clubs (i.e., AA UK, ACI Italy, ADAC Germany, ANWB The Netherlands, ÖAMTC Austria, TCB Belgium, TCS Switzerland, and RACE Spain) (ARC Transistance, 2007). The process innovation – providing mobility related services to the motoring industry and transnational membership assistance services – is challenging as different teams and countries with different cultural backgrounds, systems and methods are cooperating.

Grand sporting events: e.g., Olympic Games are a set of different sub-projects that include the facilities for competitions and housing of the athletics, provided by different organizations and teams. As Grün (2004) has shown in different case studies on Summer and Winter Games, there are often high cost overruns (e.g., Winter Olympics 1994 in Lillehammer had a deficit of $700m) and remarkable reductions in quality like collapsing transportation systems (e.g., Olympic Winter Games 1980 in Lake Placid).

Space-research technology: e.g., the International Space Station ISS: National Aeronautics and Space Administration NASA, Russian Federal Space Agency, European Space Agency ESA, Japan Aerospace Exploration Agency JAXA, and Canadian Space Agency CSA have signed the 'International Space Station Intergovernmental Agreement' (IGA) in January 1998. It is a cooperative program for the joint development, operation and utilization of a permanently inhibited Space Station in the low Earth orbit (ESA, 2006). This involvement of many different teams and nations can be problematic. For instance, in April 2001 a computer failure led to a major disagreement over which nation should deliver what part for the station (BBC science, 2001).

Figure 1.1 Examples of MOMT projects in different fields

made for the other teams in the systems' project – brackets and walls were found in these different sections where none were supposed to be. Therefore workers had to remove entire bundles of wiring and start over, including getting new wires from the suppliers; thereby exceeding schedule and budget.

Delays of more than one year cost Airbus several billion euros. For instance, the first A380 was delivered to Singapore Airlines in October 2007, 18 months behind schedule. Delays like this caused further problems for Airbus, as customers canceled their order and swapped for the rival plane maker Boeing (e.g., in November 2006 FedEx scrapped its order for ten A380s as a result of the delays, electing instead to buy 15 Boeing 777 planes), or they will get better deals from the beleaguered plane maker. Compensation is also likely, which some analysts forecast could reach two billions euros (e.g., in December 2006 Qatar Airlines was the first to seek A380 payback). Based on these problems, in October 2006 Airbus already had to tell its shareholders that it would have to sell 420 A380s – 150 more than previously estimated – before it could expect to make a profit.

This example and the ones in Figure 1.1 show that it is very difficult for MOMT projects to perform well. The typical challenges of NPD projects – being on time, within budget (efficiency), and/or meeting product specifications and requirements (effectiveness) – become even more challenging because of the complexity of the product to be developed and (thereby) of the project itself.

In this research two MOMT projects in the field of space research are studied, in which a highly complex technology-intense new product is developed in a collaboration of many teams with members from different organizations. As these projects each are a part of larger complex projects it is expected to see the characteristics of very complex projects within the studied ones.[2] It is assumed that they face similar challenges like the examples given above. For better illustration, excerpts from interviews conducted with team leaders are integrated below.

When developing new products there is a high degree of non-routineness. There is no previously applied procedure that specifies the sequence of steps to be followed in performing the tasks – low task analyzability and predictability (Perrow, 1967) – like a team leader of the studied space-research projects emphasizes:

[2] A more detailed description of both projects and why they were selected is given in Chapter 4 in the section on the research setting. According to agreement these studied projects were made anonymous, referring to them as 'Project A' and 'Project B'. Throughout the thesis statements that are clearly indicating the projects, teams or persons involved were made anonymous.

> “*The main challenge was that when we started this we did not know how to build any of it. And anything that I ended up delivering was invented during this project. It was all an idea in somebody’s mind but it was completely invented, none of it existed.*”

Unclear problem definitions and limited insight have an effect on the start of a project. Uncertain decisions made in early phases of the project can also have an impact in the later phases. Designing, thus, is a challenging activity if the solution for the design problem and how it should proceed is not specified (Cross, 2000). This typical NPD challenge is already a problem within teams when the members do not know how to build a part of a product. But it becomes particularly challenging in MOMT projects in which complex new products are developed. The numerous tasks are assigned to teams and members from different organizations that need to solve the complex new design problems in collaboration. Between the teams interdependencies are due to technical interfaces, and within teams the members are dependent on each other to jointly build a part of a component.

Because of the task non-routineness and task interdependence there is a substantial information-processing, hence, communication need (Bell and Kozlowski, 2002; Shenas and Derakshan, 1994; Tushman, 1978b). As complex design tasks are non-routine, changes are likely to occur because the tasks and procedures of how to accomplish them is difficult to preplan (Emmanuelides, 1993). Additionally, some design interfaces are not foreseen at the outset of the project and are only discovered when teams are working on the components (Sosa et al., 2004). During the task execution more knowledge is acquired which leads to changes in resource allocation, schedules, and priorities (Galbraith, 1973), and also in the interfaces (Hoegl et al., 2004).

Thus, due to the complexity of interrelations between the components, changes in one component generate unexpected imbalances in the other components (Frenken, 2001), which affects the work of multiple teams (Hoegl et al., 2004) as highlighted by a team leader:

> “*The main challenge is, when something changes make sure that everybody that needs to know is informed in a timely manner.*”

These unanticipated and novel events require different methods or procedures for accomplishing the tasks – high task variability (Perrow, 1967). As Tushman (1978a, 1979) highlights, the greater the rate of change, the greater are the already complex information-processing requirements.

Within MOMT projects, team members and teams, thus, need to communicate to jointly solve complex design tasks. Through communication, team members make individual knowledge accessible to members of the same group and of other groups (Souder and Moenaert, 1992). Their different expertise can be shared and combined to generate new knowledge and transfer important information. However, due to the involvement of many different functions, teams, and organizations in the project – despite the advantages of having direct access to the diverse expertise and information required – there may be a multitude of problems in the communication process.

The team members are often so specialized that they only have function-specific knowledge and do not know about the parts of the product members of other functions are working on; or they have different priorities (Cooper, 2003) or understandings and interpretations of the development process (i.e., different 'thought worlds': Dougherty, 1990). In MOMT projects this can be intensified because of the differentiation into different teams according to design tasks. Such specialized sub-units (teams) may develop idiosyncratic norms, values, languages and coding schemes which make communication across boundaries difficult and prone to distortion, which then can negatively affect performance (Malhotra et al., 2001; O'Sullivan, 2003; Tushman, 1979).

Moreover, in MOMT projects challenges arise because different organizations are working together. There can be a 'communication dilemma' (Bonacich and Schneider, 1992) when the project's interests demand that people share discretionary information but their interests and desires for gain motivate them to withhold it (Monge and Contractor, 2003). This opportunism risk is frequently named in collaboration literature. For instance, a very striking case of a communication dilemma has been recounted by Bonacich and Schneider (1992) which in 1986 led to the destruction of the US space shuttle Challenger, killing all the astronauts aboard. The senior management at NASA had failed to share enough safety-related information among the separate divisions.

There is a plausible relationship between communication and performance in NPD, which has also been found in literature (e.g., Hoegl et al., 2004; Kratzer, 2001; O'Sullivan, 2003). As Pahl and Beitz (1992) state, the development of a new product demands a constant flow of information. They further argue that in NPD, professionals need to work in a systematic way to realize a modern approach that is flexible, allows for task variety, and is capable of being planned, optimized and verified (Leenders et al., 2007). A systematic approach in the design process, hence, has become common to coordinate and manage complex NPD projects under risk and time pressure. There are different systematic design principles underlying modern design methodology (Pahl and Beitz, 1992) that affect communication of NPD team members (Leenders et al., 2007), which will be introduced and discussed in Chapter 3.

Hence, these two aspects – communication and systematic design approach – are essential when studying influences on performance in MOMT projects.

1.2 Communication and Systematic Design Approach in Multi-Organization, Multi-Team Projects

Team members and teams have to communicate in order to successfully develop a complex new product within time and budget restrictions and according to the specifications and requirements. They were assigned based on their expertise that needs to be exchanged and combined into new knowledge in order to jointly solve the complex design problems. That means they need to tap into an appropriate network of information flows (Kratzer, 2001) – patterned information dissemination through communication among persons (Allen, 1977).

Since certain types of communication may be beneficial for work in innovative settings, and the focus is on design problem solving, "performance may be positively associated with communication related to generating, sharing, and/or evaluating new ideas or solution approaches", but not with communication on organizationally related problems (Katz and Tushman, 1979: 140f.). Therefore, in this research only communication on problem-solving – not on managerial or non-work related – issues is studied. As Von Hippel (1990) emphasizes, design problem solving and the generation of new information is the core function of innovation project tasks.

As the increasing complexity of new products engenders a greater need for information processing (Emmanuelides, 1993; Hoegl et al., 2004; Tushman and Nadler, 1978), problem-solving communication is particularly crucial in MOMT projects. Complex problem-solving situations require a specification of possible solutions and the selection of an alternative among a set of possible alternatives (Becker and Baloff, 1969). For such knowledge-intensive work, high interactions within and between teams is needed (Perlow, 1999). Obtaining and sharing internal and external information helps team members to understand the design process more quickly and fully from different perspectives, which in turn improves the design process performance (Brown and Eisenhardt, 1995).

In order to develop new products effectively and efficiently persons' diverse expertise has to be brought together in a coherent way (Clark and Wheelwright, 1993). This means not everyone needs to communicate with everyone in the MOMT project. Effective communication is required for providing the necessary information to the right people at the right time (Cooper, 2003; Katzenbach and Smith, 1993; Lipnack and Stamps 1997).

With a systematic design approach the complex project and design processes, and thereby the information flow within and between teams, can be structured and managed. On the one hand the communication need can be reduced, while on the other hand the required communication is facilitated. The problem-solving activity, hence communication, should mainly take place *within* teams where the

Figure 1.2 Preliminary conceptual model

team members with their complementary expertise are jointly solving the assigned design tasks. For this creative and innovative design process a context must be created that facilitates the emergence of solutions (Girard and Robin, 2006). When team members work in a systematic way they can handle the task complexity (Pahl and Beitz, 1992) as they communicate accordingly, which contributes to team performance and overall project success.

To perform well, problem-solving communication *within* and *between* teams is important and needs to be managed by a systematic design approach. These two relations, presented in the preliminary conceptual model in Figure 1.2, are thus central in this research.

1.3 Research Purpose and Questions

In the discussion above, the challenge of how to successfully manage the teams and MOMT projects in the complex NPD process has been highlighted. There is a need for knowledge on how communication affects performance in order to benefit from the required collaboration within and between the teams with specialized members from different organizations.

In contrast to NPD projects with a single team that has to meet the product specifications and requirements on time and within budget, in MOMT projects the teams not only need to perform well separately (team performance) but also in collaboration (project performance). As Hoegl and Weinkauf (2005: 1288) emphasize: “Managing the intense task interdependencies […] is likely to be critical to the success of multi-team projects, as the work and output of any single team has consequences for the work and output of other teams in the project”. Teams need to solve the complex design problems together so that the entire product, hence the project, can perform well.

Therefore the focus of this research is on the effectiveness and efficiency of both teams and the MOMT project as a whole.

Not much research has been done on such complex projects. As, for instance, Mihm and colleagues (2003: 735) state: “Managing size and complexity of an NPD project has not received widespread attention in the empirical literature”. In recent years, there have been studies either on multi-team projects within a single organization (e.g., Hoegl et al., 2004; Hoegl and Weinkauf, 2005; Kazanjian et al., 2000; Sosa et al., 2004) or on a single multi-organization team (e.g., Majchrzak et al., 2000; Malhotra et al., 2001). But only few researchers have studied multi-organization, multi-team projects. For instance, Argyres (1999) and O'Sullivan (2003) have conducted case studies in the aerospace industry; and Grün (2004) has studied the challenges and failures of different 'giant projects' in the public transportation and of grant sporting events. More (quantitative) research on MOMT projects still needs to be done to reveal variables that have an (in)direct influence on performance and to be able to generalize findings for successful management. This study aims to make a contribution to this field of research.

In this research, a closer look is taken at the two relations presented in the preliminary conceptual model (see Figure 1.2), investigating three main research questions – one for each relation, plus one for the comparison of those two on different levels of analysis.

The first main research question refers to the influence of problem-solving communication on performance. It is studied on two levels of analysis – the team performance and the project performance – in two MOMT projects in the field of space research:

1) ***What is the influence of problem-solving communication within and between teams on team and project performance in MOMT projects?***

These two levels of analysis are referred to as the local level and the global level respectively. Team performance on the local level is expected to be dependent on both the communication *within* the teams and *with other* teams of the project (cf. Brown and Eisenhardt, 1995; Hoegl et al., 2004; Hoegl and Weinkauf, 2005; Keller, 1994; Souder and Moenaert, 1992), whereas project performance on the global level will only be influenced by the communication *between* the teams (cf. Chiu, 2002; Emmanuelides, 1993; O'Sullivan, 2003; Sosa et al., 2004; Tushman, 1977).

The three different networks of problem-solving communication are shown in Figure 1.3. The communication among team members (TM), including the team leader (TL), within teams is termed as *intrateam* communication – the communication on the local level within the team boundary (shown by the circle around the network). For research purposes the communication between teams (T stands for the whole team, comprising the team leader and team members)

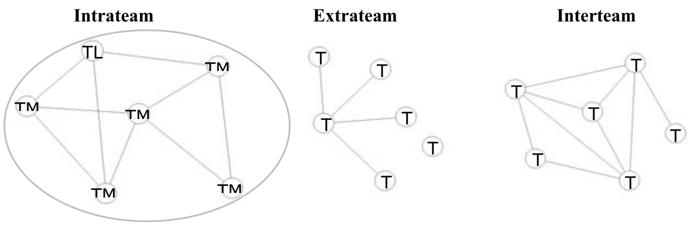

Figure 1.3 Intrateam, extrateam and interteam problem-solving communication

is distinguished into extrateam and interteam communication. *Extrateam* communication refers to a given team's communication with the other teams in the MOMT project – the local level. In contrast, *interteam* communication defines the interaction among all teams in the project – the global level. This means the communication network of the MOMT projects as a whole is studied.

Based on the above discussion on the different problem-solving communication definitions and influences, the first main research question is addressed by the following three sub-questions:

1a) What is the influence of intrateam problem-solving communication on team performance in MOMT projects?

1b) What is the influence of extrateam problem-solving communication on team performance in MOMT projects?

1c) What is the influence of interteam problem-solving communication on project performance in MOMT projects?

In Chapter 2, the first two sub-questions are discussed and hypotheses are derived. The third sub-question is addressed in Chapter 6.

In MOMT projects, a systematic design approach is needed to structure and facilitate the information exchange for solving complex design problems. This dependence is studied in the second main research question:

2) What is the influence of a systematic design approach on problem-solving communication within and between teams in MOMT projects?

The influence on the different variables of problem-solving communication need and process studied in the second chapter is investigated by the first two sub-questions:

2a) What is the influence of a systematic design approach on intrateam problem-solving communication in MOMT projects?

2b) What is the influence of a systematic design approach on extrateam problem-solving communication in MOMT projects?

To answer these questions, in Chapter 3 hypotheses on the distinct influences of the systematic design approach are derived. The discussion and derivation of the hypotheses on the variables of the direct and indirect influences on team performance in Chapter 2 and 3 leads to a refined conceptual model for the local level (see Figure 3.1).

In Chapter 6 on project performance, the dependence of interteam problem-solving communication on a systematic design approach is studied by the third sub-question:

2c) What is the influence of a systematic design approach on interteam problem-solving communication in MOMT projects?

For that global level, the discussed direct and indirect influence on project performance – answers to sub-question 1c and 2c respectively – is shown in a refined conceptual model in Figure 6.5.

Having answered the first two main research questions, the third question about whether similar effects can be found for the local as well as global level can be answered in Chapter 6:

3) ***Is there a difference in the studied relations between the local and global level of MOMT projects?***

The way these different research (sub-)questions are answered is described in the chapter on research design (Chapter 4), where a more detailed description of the two studied MOMT projects, the data-gathering process, and the different methods, measures and analyses is given.

In Chapter 5 the results of hypotheses testing are presented and discussed, addressing the sub-questions 1a, 1b, 2a and 2b. The sub-questions 1c and 2c are addressed in Chapter 6 when analyzing the direct and indirect influence on project performance in a case study of the two MOMT projects.

In Chapter 7 the findings of this research are summarized. Conclusions are drawn on how teams of MOMT projects can be managed so that both the teams and the project are successful. In addition to these theoretical and practical implications, research implications are also given, discussing the strengths and weaknesses of this research.

The study outline is graphically presented in Figure 1.4. It shows the two research streams of team performance (the local level) and project performance (the global level) that lead to conclusions on how to successfully manage teams of MOMT projects and the project itself.

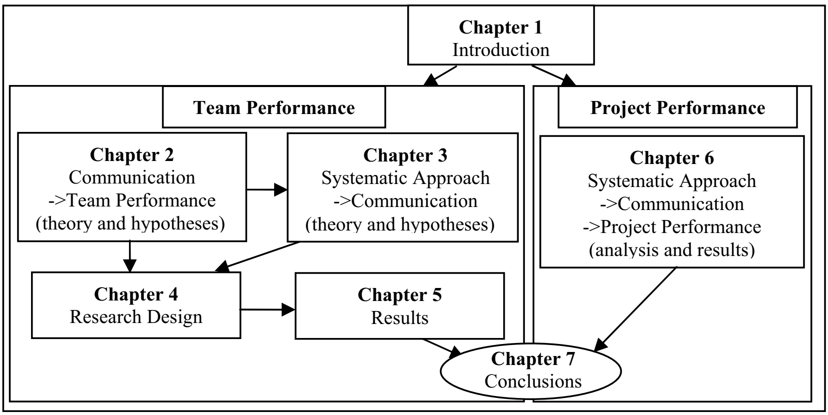

Figure 1.4 Outline of study

As different variables are studied in this research, in the following chapters (i.e., 2, 3, 5, and 6) – when contributing – along the outer margin of the pages a ‘guidance’ for the reader is given. The two performance aspects are represented by:

🗐 effectiveness (‘meeting product specifications and requirements’)

🕒/€ efficiency (‘being on time and within budget’)

The icons for the problem-solving communication variables are taken from the defined networks (see Figure 1.3):

 intrateam communication (within teams)

 extrateam communication (with other teams)

 interteam communication (between all teams)

To further specify the communication variables studied – see discussion in Chapter 2 (Section 2.2) – three abbreviations are used:

FREQ communication frequency

TLR team leader role

TDIS task disagreement

To refer to the systematic design principles that are discussed in Chapter 3 the following icons are applied:

 hierarchical decomposition of a project according to design tasks

 systematic variation (picture of a morphological chart)

☺ satisficing (‘suffice the requirements and satisfy the wishes’)

This study on MOMT projects has scientific as well as practical relevance. As previously stated, there is a gap in the literature about such projects and although they are becoming more common, they are still very challenging. Therefore it is important to inform managers as to how problem-solving communication influences team and project performance, and how it depends on the systematic design approach applied. This need is also highlighted in the statement of a team leader of the studied MOMT projects:

> “*We have a sort of new style of collaboration which isn’t handled by an old style of management rules.*”