A STUDIO BASED APPROACH FOR BUSINESS ENGINEERING AND MOBILE SERVICES

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PROEFSCHRIFT

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To my Mom, to my Dad,
and to my dear wife Dongni.

Colophon

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PREFACE AND ACKNOWLEDGEMENTS

In today's world, organizations are becoming increasingly interested in using advanced technology as a means to adapt to the ever-changing environment. An important challenge organizations need to meet is to find ways to support efficient and effective business process between their managers and their mobile workers in the distributed environments. In the research presented in this thesis, we examined mobility issues as a part of today's organizations' engineering effort, and developed a simulation based support studio to facilitate this process that consists of an approach and software suite, that can be used to assist organizations to design mobile workforce solutions with a focus on process performance improvement.

I am indebted to many people for their help in the last four years as I traveled along and completed my PhD research journey. First and foremost, I would like to thank my promoter, Henk Sol, for providing me with the opportunity and freedom to conduct this research. His care and valuable comments guided my path academically and taught me how set my priorities and to put family first.

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Yan Wang
Delft, December 2007

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1.1 Introduction

1.1.1 Business Engineering and IT

The changing economic environment requires organizations to be able to use information better, to learn faster, to be proactive rather than reactive, and to foster innovation while managing risks. All of these requirements imply a need for significant organizational transformation (Grotevant, 1998).

The term Business Engineering (BE) has become popular in the business and information systems literature and is used to denote organizational transformation focusing on the integral design of information technology (IT) and organizational processes and structures (Davenport, 1993; Davenport & Short, 1990; Dennis, Daniels, Hayes, & Nunamaker, 1993; Fried, 1991; Grover, Teng, & Fiedler, 1993; Hammer, 1990; Kaplan & Murdock, 1991; van Meel, 1994; van Meel & Sol, 1996; Vogel, Orwig, Dean, Lee, & Arthur, 1993).

Three different forms of Business Engineering can be distinguished in (Smith & McKeen, 1993):

- *infrastructure engineering,* which deals with strategic choices about partners, markets and products, and has always been part of the job of executive management
- *process engineering,* which concentrates on changing technology and the user environment in an integral way
- *task engineering,* which deals with job design and screen layout and has been the job of industrial engineers and system analysts for years.

Business Engineering looks at organizations from multiple perspectives, but *hinges* on the process dimension (Andrews & Stalik, 1994; Hammer & Champy, 1993; Knorr, 1991; Morris & Brandon, 1993; Stalk, Evans, & Shulman, 1992; van Meel, 1994). Infrastructure engineering without process engineering is often ineffective (Streng, 1993; van Meel, 1994). Business processes need to be redesigned and restructured, for successful implementation of strategic choices (Davenport, 1993; Morris & Brandon, 1993; van Meel, 1994). Task engineering without looking at businesses as a whole can easily result in suboptimizations (Hall, Rosenthal, & Wade, 1993; Hammer & Champy, 1993; Harrington, 1991; van Meel, 1994). In this research, we take the process engineering perspective on BE, because this enables us to link the technology and the user environment, which is core for an organizations' BE effort.

The "process" in the term "process engineering" mainly refers to a business process. A business process is a special process[1] that is directed by the business objectives of a company and by the business environment (Nordsieck, 1972). Examples of business processes include order processing in a factory, a retailer's routing business, and credit assignment at a bank (Becker, Kugeler, & Rosemann, 2003). Terms such as "process engineering", "business process (re) engineering" and "(re) engineering business processes" are used interchangeably in the literature, and they all refer to the effort required to move towards effectively using emerging information technologies and strategic alignment to redesign business processes to achieve operational efficiency and business success (Tsai, 2003).

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[1] A process is a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure for action (Davenport, 1993)

Many researchers have discussed the role of IT in BE (i.e.(Attaran, 2004)). Classically, IT has been considered as a strategic catalyst and as an enabler of BE (Davenport, 1993). For example, desktop computing in the 1980s and 1990s served as a catalyst for the re-engineering movement; the Internet and WWW can be viewed as catalysts for the radical change in business context and business process viewpoints (Kim & Ramkaran, 2004). The latter is what Keen and McDonald (2000) term the "e-process" perspective, with the assumption that there are no barriers between departments and enterprises.

While the "e-process" perspective continues to impact the global business environment profoundly, technologies and applications are beginning to focus more on mobile computing and the wireless Web. Leung and Antypas (2001) suggest that mobile technology can be used to enhance business efficiency by distributing information to the workforce remotely and by offering new channels customer interaction. The leadership in many major firms is aware of the gravity of this technology shift and is making significant efforts to transform their business designs and competencies to adapt to this new environment successfully (Kalakota & Robinson, 2002). To help us to continue the discussion on this issue, the term "mobile services", which generally refers to services enabled by mobile applications and technologies, is introduced in the next section.

1.1.2 Mobile services

Mobile services are defined as the delivery of information, communication, and transaction using a mobile device, i.e. smart phone and PDA (van de Kar, 2004)[2]. To pursue a deeper understanding of the concept, we will break it down into two parts: *service* and *mobile device*. We argue that mobile services are in nature the services delivered through mobile devices. Hence, they have common characteristics being services, and also have features imposed by mobile devices.

The term *services* is used to represent non-tangible products that create value for the person(s), or organization (s) receiving them, e.g. a rental subsidy, an electronic travel booking, a learning experience, or a discussion forum to support customer communities (Verbraeck, 2003). Services are found in an interorganizational setting, such as business to consumer, business to business and business to government, and within organizations. Examples include teaching and learning services, and coordination and collaboration services (Verbraeck, 2003).

The service marketing literature abounds with definitions on traditional services and delivers generally accepted characteristics of services (e.g.(Gronroos, 2000)). The following three characteristics are relevant for mobile services (van de Kar, Eldin, & Wang, 2004). Services are *heterogeneous*, every service produced through interaction is unique to a certain degree. Furthermore, services are *intangible*, but at the same time they are coupled to products. This is especially true for mobile services because they imply intermediation by ICT-applications via a device; for instance, you need a mobile phone to receive a SMS. Thirdly, services are *perishable*, their value is gone with the act of consumption. This is why it is hard to quantify the value of a service: it is hard to put a price on an evoked feeling or a delivered experience.

Mobile devices can be wireless and non-wireless. According to (Kalakota & Robinson, 2002), wireless commonly means *mobile but online*: there is a real-time live Internet connection via satellite, cellular or radio transmitters. Non-wireless can be understood as *mobile but offline:* the device runs self-contained programs but is not connected to the Internet, which can interface with other devices and networks through wired synchronization, often using wired cradles or infrared

[2] There is an overwhelming amount of discussion on the definition of mobile services in the literature. We adopt van de Kar's definition as a line of reasoning.

'beaming'", for example a synchronized PDA (Kalakota & Robinson, 2002; Tarasewich, Nickerson, & Warkentin, 2002)[3].

The focus here is on services delivered through wireless mobile devices, given the fact that non-wireless mobile devices are likely to be replaced by wireless ones in the future. Currently, wireless mobile devices include wireless phones, wireless-enabled handheld computers, i.e. pocket, palmtop, and tablet computers, laptop computers, vehicle-mounted technologies, and personal message pager devices (Tarasewich et al., 2002). Though all these devices belong to the category of points of access to the existing Web and Internet, their usage patterns differ from those of traditional stationary machines. This is because the interaction style is unique, due to the constraints of smaller screen sizes, limited or nonexistent keyboards, and other limitations of the devices. The content of the communication is also unique, due to the current bandwidth constraints imposed by public frequency limitations (Waters 2000).

In light of the nature of mobile devices, services delivered through them are characterized by "mobility" and are hence driven by the mobile value. (Anckar & D'Incau, 2002) have identified five different settings in which mobile value is created:

- time-critical arrangements
- spontaneous decisions and needs
- entertainment needs
- efficiency ambitions
- mobile situations

Many organizations in a wide range of vertical industries are exploring the mobile value in their business settings. A typical area full of mobile value could be the business segments, i.e. maintenance and repair of machinery at the customer sites, conducted by mobile workers. Mobile workers are considered to be people whose professional tasks can only be completed in a "mobile environment", where this refers to the user's mobility and the lack of wired infrastructure for telecommunications (van den Anker, 2003). Examples of mobile workers are salespeople in the field, traveling executives, people working in corporate yards and warehouses, and repair or installation employees who work at customers' sites. Mobile value can be illustrated by the scenario that these mobile workers need the same corporate data available to employees working inside the company's offices. For instance, a salesperson might be on a sales call and need to know the recent billing history for a particular customer. Or a field service representative on a service call might need to know the current availability of various parts required to fix a piece of machinery (Turban, King, Lee, & Viehland, 2004).

Mobile services should provide seamless combination of voice, video and data communications to exploit the potential for mobile workers anytime and anywhere. Furthermore, mobile services provide the opportunity for organizations to conduct business in innovative ways considering that "the traditional limitations of time and space are disappearing" (Tsai, 2003). For instance, mobile services' nearly ubiquitous availability enables direct software support and information access for many new business functions in real time that were previously unsupported by IT because these tasks were performed remotely (Tarasewich et al., 2002). A number of generic mobile services classified by their applications are proposed and described by (Varshney & Vetter, 2001), for example mobile financial application, mobile inventory management, proactive service management, product locating and shopping, mobile office, mobile distance education and wireless data centre.

[3] In the remaining part of this document, we will use the term *mobile* broadly to refer generally to online and offline situations.

In conclusion, mobile services can be used to break down the barriers to information access, can enhance communication and collaboration, and allow users to perform various commerce-related tasks without regard to time and location. The value for certain groups of users (mobile workers) in certain conditions (mobile environments) determines that application areas for mobile services are mainly in industries with "mobile workers", i.e. repair and maintenance, insurance, and the police. It is in these domains that mobile services grant opportunities for innovation that requires business (re) engineering. Thus mobile services can be used to enable a new wave of BE in certain industries.

1.2 Business engineering and mobile services

Holding a business process perspective, we argue that mobile services are emerging enablers for improving business processes or designing new business processes, they create new spaces for applying BE and also bring many challenges. In this early stage of BE enabled by mobile services many questions are being discussed and remain unanswered, for example:

- Which sectors and organizations might enhance their performance by supporting their mobile working processes with mobile services?
- How can the added value be measured? Will mobile services change the whole business processes dramatically?
- How can a "batch processing" be transferred to a "real-time responding", i.e. a real-time response to obtain real-time information and to send planning results rapidly to the field?
- What are the organizational impacts? For example, mobile workers get more information and do more work than before, and back office employees will be released from some tasks.
- How can senior management be convinced of the innovative use of mobile service in process reengineering? (adaptation of (Wu, 2003))
- How can new, coordination-intensive structures be developed to enable organizations to coordinate their activities in ways that were not possible before?
- Will coordination be a new issue? How can the new type of coordination be adopted?

Some of these are common questions faced by any BE project, and some are new questions characterized by the possibility to use mobile services, which to date have not been well studied and practiced. An important issue is how mobile services differ from traditional Internet based services in ways of enabling processes (re) engineering within organizations. The personalization, location specificity and ubiquity of these services, for instance, are seen as important characteristics that make them different from "E" (Internet based) services.

Our research interests are based on the many questions that require answers to be found at this moment. As shown in Figure 1.1, the research field forms an interface between two research fields, mobile services and business engineering. Knowledge of both sides is required for a study in this specific field. We use term "*business engineering and mobile services*" (BEaMS) to denote this field, this describes the efforts of organizations to "harness the power of mobile technologies to automate and streamline business processes in order to reap the benefits of improved productivity, lowered operational cost, increased customer satisfaction, and improved decisionmaking" (Varshney, Mallow, Jain, & Ahluwalia, 2002).

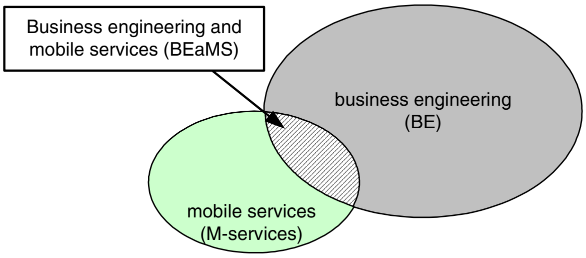

Figure 1.1 Research field

Current research and practice has shown the complexity of this research field and highlighted the challenges that need to be met when doing research in this field. Kalakota and Robinson (2002) use the term "mobility-enhanced" to characterize the new set of business processes and point out that implementing mobility-enhanced internal and external business processes will be difficult and challenging because there is a lack of theories and methods available as yet to cover. The voice from industry is consistent with Kalakota and Robinson's analysis, and can be illustrated by a case study: Pepsi wanted to streamline its business process using mobile services (for the full description, see (Hayes & Kchinskas, 2003); a brief introduction is given below).

Pepsi's delivery agents used to forecast their sales each day, and their trucks would be loaded with a "guesstimate" of the orders for the day. Delivery agents would head out to their 14 to 20 delivery calls each day, cut invoices based on what customers actually needed, and bring back a lot of product on the truck. There was a lot of inefficiency in this system, which required too much haulback and put excess burden on warehouse workers.

…

Pepsi decided to transition into "pre-sell" mode-it split tasks between its sales and distribution system so that sales reps will focus on products, pricing, and distribution, and the delivery agents can focus on getting products to the customers. The company now has 1000 to 1500 sales representatives out in the field, visiting anywhere from 15to 25 accounts per day. The sales reps take orders on their mobile devices, then transmit them via wireless connection (or via synch mode if it isn't wireless coverage). Orders are then aggregated, routed and dispatched out to delivery drivers. …

The biggest challenge that Pepsi faced during the study was that of dealing with the new business process that resulted from the use of mobile services. The project manager realized the company's business process change was bigger than the technology change. "Some times it's hard to determine if a problem is a technology issue or a business process breakdown", said by the project manager. The Pepsi "reengineering" pilot project failed because it was focused more on technology change than process change.

We summarize the challenges in this field (BEaMS) as follows.

- The classic BE approach is based on "E" (electronic) services that are enabled by IT technology. "M" (mobile) services expand the boundary of "fixed" E-services. BEaMS has to take this into account, and responds accordingly.
- BEaMS is a change process within an organization. This change is about the structure of the organization and is not "radical" (Kalakota & Robinson, 2002). The new organization can be regarded as an intermediary between "physical organization, i.e. traditional IT supported organization" and "virtual organization, i.e. full distributed organization". Interpreting the organizational thinking in BEaMS is challenging.

- The coordination along the business processes needs particular care in BEaMS, taking into account that organizations can now coordinate their activities in ways that were not previously possible.
- The human factor is important in BEaMS. It is important to deal with the people involved, from field workers, to managers and business process designers.

1.3 Simulation as a method of inquiry

Shannon (1975) defines simulation as "the process of designing a model of a concrete system and conducting experiments with this model in order to understand the behavior of a concrete system and/or to evaluate various strategies for the operation of the system". In general, two contributions of simulation are stressed in the literature. Firstly, simulation of business process creates added value in understanding, analyzing, and designing processes by introducing dynamic aspects, and it provides decision support based on anticipation of future changes in process design and improves understanding of processes (Aguilar, Rautert, & Pater, 1999). Secondly, "simulation of possible new situations as described by the design models should then help in identifying and solving co-ordination problems that will occur in those new situations" (Sol & Bots, 1988).

From a BE perspective, simulation is a proven method of inquiry that provides more insight into the process and their quantitative metrics (den Hengst & de Vreede, 2004). Sol's dynamics modeling approach (Sol, 1990) has been used as a framework for simulation-based inquiry in a number of business engineering projects. Each of them has focused strongly on the modeling of complex organizational processes to evaluate the effects of introducing information technology into organizations. It has become clear that dynamic modeling can be of value for supporting BE (van Meel, 1994). The description of this approach is structured by looking at the ways of thinking, working, modeling, and controlling (Sol, 1990). We refer to (de Vreede, 1995; Janssen, 2001; van Eijck, 1996; van Laere, 2003; van Meel, 1994) for a comprehensive description of the dynamic modeling approach.

The way of thinking provides an underlying structure and organization of ideas that constitutes the outline and basic frame, which is used to guide a modeler when representing a system in the form of a model (Sol, 1982). The way of thinking covers the philosophy on which the methodology relies and gives a perspective on the problem domain and the way in which the problems can be solved. In this research, we adopt a systems perspective on organizations and their business processes.

According to such a perspective an organization can be seen as an purposeful or even purposive system: a structured set of interrelated actors and activities that perform certain organizational functions to fulfill demands of its environment (de Vreede, 1995; Sol, 1982; van Laere, 2003). We therefore can apply systems methodology in this research, which is regarded as "a concept of and reasoning principles for integrating traditional engineering problem solving with systems theory, management science, behavioral decision theory" (Nadler, 1995). A comprehensive description on systems methodology can be found in (Jackson, 1991).

Importantly, using a systems methodology implies a problem solving focus. In this research, engineering the businesses processes enabled by m-services is illustrated as a complex process, and it can be seen as solving an ill-structured problem[4]. An ill-structured problem is defined as a problem that does not meet the requirements of a well-structured problem (Sol, 1982). We follow Sol in defining the requirements of a well-structured problem as follows (Sol, 1982):

- the set of alternative courses of actions or solutions is finite and limited

[4] Also see (Simon, 1973)

- the solutions are consistently derived from a model system that shows a good correspondence
- the effectiveness or the efficiency of the course of action can be evaluated numerically.

A problem oriented way of thinking grounded in a systems perspective will be used for this research.

The way of working concerns the steps of a dynamic modeling approach that need to be taken to cope with the specific characteristics of our problem situation. Given the problem oriented thinking approach used in this research, the way of working follows a problem solving process. A problem solving process model is given by Sol (1982) based upon (Mitroff, Betz, & Sagasty, 1974), as shown in figure 1.2. Although many possible processes can be derived from different combinations of the activities included in this model, in this research we follow Sol (1982) and adopt the following problem solving process.

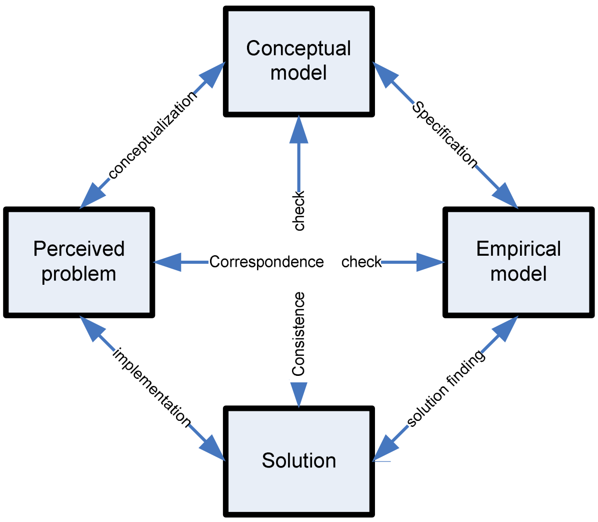

Figure 1.2 Problem solving process

In this process, four *stages* are illustrated linked by *activities*. The four stages are the perceived problem, the conceptual model, the empirical model and the solution. The conceptual model defines the variables that will be used to specify the nature of the problem in broad terms. The empirical model specifies the conceptual model in term of the system.

The first activity in the process is the creation of a mental model of the current problem situation. The second activity is to make a detailed specification of the problem situation to construct a *descriptive* empirical model, the "as is" model. Before this model can be used to diagnose the problem situation, it has to be tested to determine if it is a sound representation of the problem situation. This activity is called a correspondence check. The next activity is to analyze the problem situation and generate solutions for it based on the empirical model. Solutions are translated into the terms of the empirical model, transforming the *descriptive* empirical model into a *prescriptive* empirical model, the "to be" model, or an experimental model. Solutions generated by the empirical model that shows a good correspondence, have to be consistent. The consistency check activity is used for this purpose. Finally, in the last activity of the problem solving process the solution has to be implemented in the organization to solve the problem situation.

As we have discussed, the problem solving process emphasizes the use of models as substitutes for complex reality. *The way of modeling* concerns the choice of modeling techniques, and the construction and application of models during a study. The purpose of a model is to reduce the complexity of understanding or interacting with a phenomenon by eliminating the details that do not influence its relevant behavior (Curtis, Kellner, & Over, 1992; Janssen, 2001). Hence modeling can be informally defined as "the art and science of leaving out"(van Meel, 1994).

The number of different modeling techniques available is immense and there are different ways to distinguish them. One way is to look at modeling languages. Four categories of modeling languages are discussed in (Wijers, 1991) as follows:

- free models: only restricted in their structure by the model builders' imagination
- structure models: generally represented in diagrams, tables, matrices or structured text
- mathematical models: defined by applying languages based on mathematical constructs
- dynamic models: offer experimentation facilities, such as simulation models and prototypes. Note that simulation is regarded as a type of modeling.

Modeling techniques can also be distinguished by looking at resulting models. For example, "task-actor modeling" (Bots, 1989; Dur & Bots, 1992) is a modeling technique used for constructing conceptual models, since it fulfils the need of providing a quick overview of current work processes and coordination mechanisms and sketching possible future alternatives. Another example is "gaming-simulation", a modeling technique used for building empirical models because it fulfils the need to experience new work processes, new coordination mechanisms and future organizational context as a meaningful whole (Geuts, 1995; Greenblat, 1988).

The way of controlling represents the managerial aspects of the problem solving process (Lohman, 1999). It includes planning and plan evaluation, establishing the project by indicating how the various persons and groups should interact, and how the generally limited recourses should be employed and allocated (Wijers, 1991). An adaptive control strategy is recommended in the current dynamic modeling approach (Keen, 1980; Sol, 1992). This control strategy implies that problem solving is an adaptive process of learning for both the designers and the participants of the organizations involved.

1.4 Research objective and questions

In section 1.2, we introduced difficulties and challenges in the research field of BEaMS, which partly explained why many companies are hesitating to implement BE enabled by mobile services. In addition, the high initial investment that is required to set up BE projects and the uncertainty regarding return of investment (ROI) are also barriers. Moreover, organizations' decision making on reengineering is related to overall business strategies, because "rethink business processes from a high-level or strategic direction is significant to the future success of process redesign (Wu, 2003)". Before huge investments are made and strategies are changed, a lot of investigation and analysis needs to be done. Given these considerations, organizations need decision support regarding how to engineer new processes in this difficult and challenging field. Such support could for instance address the creative process of conceiving potential changes, facilitate effective means of communication between the designers, management and the work force, support the evaluation of potential courses of action, guide the organization through implementation strategies, and more

(Dur, 1992). We discussed simulation as a method of inquiry, and its value in business engineering projects in section 1.3.

Research on decision support and business engineering reveals that support environments have profound effects on the outcomes of BE projects (Dur, 1992). We follow Sol (1992) in stating that a support environment should enable decision-makers to focus on the relevant design issues and treat context specific issues from various points of view. We observed that most support environments are developed in particular situations and are targeted to support certain BE issues. It is impossible to exploit any existing support environment in BEaMS directly considering its features (see section 1.2)[5]. As a result, there is a clear need for support environments incorporating the essential features of this specific field.

Therefore, the main research objective of this study is:

To develop a simulation based support environment that can be used to improve the effectiveness of business engineering and mobile services (BEaMS) in organizations.

We limited our research scope to improving the business engineering effort by taking a meso-perspective, which enables us to design effective business processes within an organization's boundary. This perspective, together with the macro- and micro- perspectives, is distinguished by (Sol & Bots, 1988) with respect to the design of organizations and their technical structures as:

- the macro-perspective, concentrating on co-operation between different organizations and on supporting and enabling technical infrastructures
- the meso-perspective, concentrating on coordinating processes that take place within the boundaries of an organization and on supporting and enabling technical architectures
- the micro-perspective, concentrating on the primary tasks that are performed at the work place level, typically by an individual or small group, and on enabling and supporting work stations.

We formulated several key research questions to help us develop such an environment. The first research question was intended to help us obtain a detailed understanding of the issues of BEaMS in real cases. An answer to this question was expected to provide us with deep insight into the problem domain.

What are the current and emerging issues in practice of BEaMS?

This first research question is answered in the first chapter and is further elaborated in chapter two with two inductive case studies. The second research question was aimed at providing a framework that can be used to guide the development of a support studio.

What are appropriate concepts to constitute the simulation based support environment?

We discuss a number of concepts in chapter three, and focus on the *studio* approach as the way forward for developing a simulation based support environment. Keen and Sol (2007) introduce the concept of a "studio" to refer to a support environment where decision enhancement is processed and achieved. The goal of using a studio is to help decision makers rehearse the future by building their confidence in directly using appropriate simulation models, information systems, analytic methods and interactive tools in their own decision processes. *Recipe* and *suite* are two kinds of

[5] It goes without saying that it is possible to make use of already established conventions for developing support.

key elements used to constitute a studio. Subsequently, the third research question considered in the research is:

What are recipes and what are contents of the suite?

This research question was designed to direct the research towards developing a new simulation based support studio. The support studio, which mainly consists of recipes and suites (software libraries), is described in detail in chapters four and five, these form the main output of this research.

The fourth and main research question was a "what" question dealing with the evaluation of the support studio.

What is the added value of using the support studio in the process of BEaMS?

1.5 Research design

The research philosophy, research strategy and research instruments are presented in this section, and a research outline is presented to clarify the structure of our research.

1.5.1 Research philosophy

All research is based on underlying assumptions about what constitutes "valid" research and which research methods are appropriate, and, to conduct and evaluate our research, it is therefore important to know what these assumptions are. For our purposes, the most pertinent philosophical assumptions are those which relate to the underlying epistemology used to guide the research. Epistemology refers to the assumptions made during research about knowledge and how it can be obtained (for a fuller discussion, see (Hirschheim, 1992)).

Orlikowski and Baroudi (1991), following Chua (1986), suggest three categories of research philosophy based on the underlying research epistemology: positivist, interpretive and critical. This three-fold classification is adopted here.

- Positivists generally assume that reality is objectively given and can be described by measurable properties which are independent of the observer (researcher) and his or her instruments. Positivist studies generally attempt to test theory, in an attempt to increase the predictive understanding of phenomena.
- Interpretive researchers start out with the assumption that access to reality, given or socially constructed, is only through social constructions such as language, consciousness and shared meanings. Interpretive studies generally attempt to understand phenomena through the meanings that people assign to them.
- Critical researchers assume that social reality is historically constituted and that it is produced and reproduced by people. Critical research focuses on the oppositions, conflicts and contradictions in contemporary society, and seeks to be emancipatory i.e. it should help to eliminate the causes of alienation and domination.

One's choice of a research philosophy will be related to the research field and the research purpose. Our research on BEaMS can be categorized as an interdisciplinary combination of organization research and information system research. The "positivism" and "interpretivism" research traditions form the basis for many studies in organizational and information system research (Orlikowski & Baroudi, 1991). For present purposes, a positivist paradigm is one in which the following assumptions predominate: reproducibility, refutation, and reductionism (Checkland, 1981). In responds to the three Rs, the researcher must try to ensure that his or her presence has no effect on the system being researched because positivist research should be objective and detached (Pidd & Dunning-Lewis, 1999). In contrast, interpretivists focus on studying phenomena in their natural environment, and maintain that researchers have an impact on the phenomena they study.

The main purpose of our research was to investigate how we could improve the effectiveness of business engineering and mobile services (BEaMS) in organizations. This purpose calls for strong engagement with the world of organizations, and therefore we chose to use the "interpretivist paradigm" during the course of the case studies, design and development of the studio. In the final evaluation phase, we chose to use an positivist philosophy, as this was considered to be more appropriate for our evaluation objective.

1.5.2 Research strategy

A research strategy consists of the steps that that have to be carried out to execute an inquiry into the phenomenon studied, and it should consist of an outline of the sequence of data acquisition and analysis required to do the research at hand (de Vreede, 1995).

Churchman (1971) distinguishes between five strategies, or inquiring systems.

1. Leibnitzian: expanding scientific knowledge by formal deduction from elementary forms of knowledge.
2. Lockean: expanding scientific knowledge by induction from sensing experiences, endowing them with properties, and combining them with previous experiences.
3. Kantian: expanding scientific knowledge by formal deduction as well as by informal experiencing through a set of "a priori sciences"; a blend of Leibnitzian and Lockean.
4. Hegelian: expanding scientific knowledge "objectively" by identifying conflicting interpretations of observations, and going beyond this conflict through synthesis.
5. Singerian: expanding scientific knowledge by adapting it "endlessly", inductively, and multidisciplinarily based on new observations.

Sol (1982) developed his inductive-hypothetic research strategy based on the Singerian inquiring system, and argues that it is most appropriate for ill-structured problems. As we have concluded that "engineering business processes enabled by m-services" is an ill-structured problem, and the aim of this research can be seen as providing support that can be used to solve this problem, it was most appropriate to use an "inductive-hypothetic" strategy for our research. This strategy is in line with the problem solving process which was presented in section 1.3. An inductive-hypothetic research strategy consists of five steps (Churchman, 1971; Sol, 1982), see also figure 1.3.

1. Initiation: using a number of rudimentary theories some empirical situations are described.
2. Abstraction: the essential aspects are abstracted into a conceptual model.
3. Theory formulation: using the descriptive model a prescriptive conceptual model is derived in the form of a theory.
4. Implementation: test the theory the model is implemented in one or more prescriptive empirical situations.
5. Evaluation: the results of the prescriptive empirical situations are evaluated.

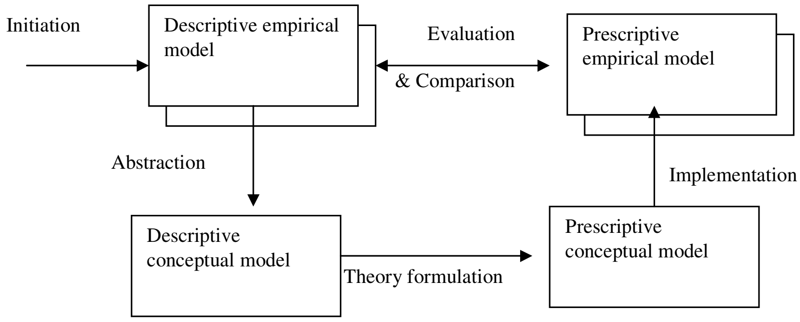

Figure 1.3 The inductive-hypothetic research strategy

This research strategy has been successfully used in a number research projects related to the design of support environments (see de Vreede, 1995; van Laere, 2003; van Meel, 1994). The concept of "theory" is used in a broad sense here; it is used to indicate an explicit and elaborated set of solutions for the original problem statement (van Meel, 1994). According to (Sol, 1982; van Meel, 1994), the main benefits of an inductive-hypothetic research strategy are that it:

- emphasizes the specification, and testing of premises in an inductive way
- opens up possibilities for a problem specification using an interdisciplinary approach
- enables the generation of various alternatives for the solution of the problem
- permits learning by regarding the analysis and synthesis as interdependent activities.

These benefits make an inductive-hypothetic research strategy very useful for new and emerging research fields such as BEaMS.

1.5.3 Research instruments

Although an inductive-hypothetic research strategy can be used to describe clearly the order and interdependence of the research steps, it gives us no indication of how to conduct the various steps. The instruments used for a given research context cover the means used to collect data on the phenomenon studies and subsequently to analyze it (de Vreede, 1995). Nandhakumar and Jones (1997) list a number of instruments commonly used in interpretive information systems research:

- analysis of published data
- textual analysis
- survey
- interviews
- passive observation
- participant observation
- action research
- consultancy

The selection of a set of instruments depends on the research philosophy used by the researcher, the current level of knowledge in a field, the nature of the research problem, the aspects of the research problem the researcher wants to focus on, the control the researcher has over the behavioral events studied, the availability of resources and even the traditions of an research institute (Benbasat, Goldstein, & Mead, 1987; de Vreede, 1995; den Hengst, 1999; van Laere, 2003; Yin, 1989). The main research instruments we employed in our research were the case study and action research.

A *case study* is defined by (Yin, 1989) as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident." Case study research has two subsets[6], observatory case studies and participatory case studies, corresponding, respectively, to the aforementioned "passive observation" and "participant observation" in Nandhakumar and Jones' terms:

- observatory case studies, where the researcher maintains a greater distance to the research subject
- participatory case studies, where the researcher interacts socially with the organizational subjects, but does not intervene

Case studies as research instruments have been successfully used in a number research projects that follow the inductive-hypothetic research strategy (de Vreede, 1995; van Laere, 2003; Sol, 1982). The following reasons may explain why case studies as research instruments are suitable for our research strategy choice (Benbasat et al., 1987):

- the phenomenon needed to be studied in its natural setting. We found that the phenomenon we were studying, BEaMS and its support, was too complex to elucidate in a constructed setting and to study using objective instruments.
- the focus was on process, namely on "how" and "why" questions. Our research question was a "how" question relating to providing support for the change process within an organization. The emphasis therefore was placed on process aspects.
- there was a lack of previous studies on the BEaMS, and our aim was to improve our theoretical understanding of BEaMS. There are an overwhelming number of studies on BE and M-services, however, few of the previous studies have taken an integrated perspective on both fields. Additionally, there was no support studio available as yet in the BEaMS field, as far as we could tell when we started our research.

Action research (AR) aims to contribute solutions for the practical concerns of people in an immediate problematic situation and to the goals of social science using collaboration within a mutually acceptable ethical framework (Rapoport, 1970). AR differs from case study research in that the action researcher is directly involved in planned organizational changes (Avison, Baskerville, & Myers, 2001).

Unlike the case study researcher, who seeks to study organizational phenomena but not to change them, the action researcher wants to create organizational change and simultaneously to study the process (Avison et al., 2001; Baburoglu & Ravn, 1992). The action researcher is viewed as a key participant in the research process, working collaboratively with other concerned and/or affected actors to bring about change in the problem context (Checkland, 1991; Hult & Lenung, 1980). In particularly, the researcher is expected to bring an intellectual framework and knowledge of process to the research context: in contrast, the problem owner brings knowledge of context (Burns, 1994; McKay & Marshall, 2001).

The requirement of combining action and research leads potentially to difficulties in controlling in AR project. Recently, attention has been drawn to this aspect and many researchers have investigated possible solutions, such as Avison *et al.* (2001), MacKay and Marshall (2001), and Mumford (2001). The findings of these research investigators were used to guide the design and implementation of our action research.

[6] Some researchers think action research is also a subset of case study, e.g. (Galliers, 1991)

Case study and action research were both used in combination during different phases of our research, as described in the next section.

1.6 Thesis outline

Chapter 2 contains a case study design, case descriptions, an analysis framework, a discussion of implications/requirements for the support environment. This chapter is designed to answer the first research question: *What are the current and emerging issues in the practice of BEaMS?*

The principles in the domain of BEaMS are introduced in chapter 3, and these played the role of a foundation which was used to direct the design of a support environment in this research. This chapter is designed to answer the second research question: *What are concepts to constitute the simulation based support environment?*

Our studio based approach for BEaMS is described in chapter 4. It contains our view on way of thinking, i.e. "landscaping guidelines"; way of controlling, i.e. "initiating guidelines"; way of working, i.e. "recipe"; and way of modeling, i.e. "suite".

The taken steps to develop the suite, features of the suite, and where and how to use the suite are explained in detail in chapter 5. Together with chapter 4, this chapter is designed to answer the third research question: *What are recipes and what are contents of the suite?*

The evaluation of the studio as a whole is described in chapter 6. This chapter is designed to answer the fourth and main research question: *what is the added value of using the support studio in the process of BEaMS?*

An epilogue consisting of a discussion of the limitations of the research, conclusions drawn based on the research questions, and a number of recommendations and suggestions for further research are presented in chapter 7.

Chapter 2 Case Studies

In this chapter we present the results of our first exploration of "business engineering enabled by mobile services" in practice. The cases investigated were based in the Netherlands, and the underlying motive for the investigation was to derive a starting point for next step of the research. The explorative case studies enabled us to get a grip on actual requirements for business engineering enabled by mobile services.

We investigated two ongoing mobile workforce projects, namely the Railpockets Connection project and the RWS Inspection project. The former is mainly targeted at the conductors of the Dutch Railway Company (NS), and the latter at the highway inspectors of the Ministry of Transport, Public Works and Water management (RWS). A mobile solution provider, LogicaCMG [7] implemented both projects, and these studies were conducted with the support from LogicaCMG.

This chapter is structured as follows. The case study set-up, including the study question, analysis units and frameworks, and the study strategy and method is introduced in section 2.1. The results of the first case study are discussed in section 2.2. It starts with an introduction of the Dutch railway's background, and business issues. Following that, the project setup, design approach and design results are described. Then we give an analysis of the project using the two frameworks presented in 2.1. Section 2.2 ends up with a discussion. The results of the second case study are presented in section 2.3, following the same structure as 2.2. We present the answer for the study question in section 2.4, and assess the implications of these results and requirements for next step of the research.

2.1 Case study setup

Our literature study, see chapter 1, showed us that using mobile solution to enhance internal and external business processes will be difficult and challenging because there is yet a lack of appropriate theories and methods available (Kalakota & Robinson, 2002). We further defined the research field of business engineering enabled by mobile services (BEaMS), and specified a number of challenges. To enhance our knowledge in this descriptive phase of the research, we realized it was necessary and important to explore and gain a better understanding of the topic. To this end, we choose to carry out two inductive case studies.

2.1.1 Study question

The main question we wanted to address in the inductive case studies is our first research question: *What are the current and emerging issues in practice of BEaMS*? In addressing this question, we wanted to elicit the design requirements for our support studio.

To address the question, we identified two aspects that were relevant, which formed the units of our analysis (see figure 2.1):

- current and emerging issues of mobile workforce solutions in organizations
- current design approaches for new business processes and the mobile workforce solutions

[7] LogicaCMG is a major international force in IT services and wireless telecom. It provides management and IT consultancy, systems integration and outsourcing services to clients across diverse markets across 34 countries.

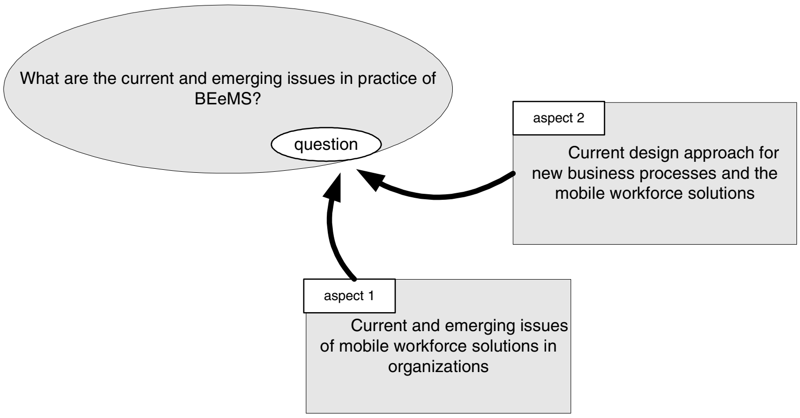

Figure 2.1 Case study questions and relevant dimensions

2.1.2 Units of analysis for two aspects

Analysis framework for emerging issues: unit of analysis for aspect 1

Gebauer and Shaw (2004) present a framework for assessing issues of mobile business applications based on the concept of task/technology fit, in term of "effective" and "efficiency", but the framework is focused on the tasks instead of the business processes. Barnes (2002) uses Porter's value chain (Porter & Millar, 1985) as a tool for analyzing issues of the mobile applications in the business; this framework is limited to examining business units that are affected in an organization's value chain.

Recalling our vision of Business Engineering, we found it is necessary to examine the issues more broadly. There are three different forms of Business Engineering, infrastructure engineering, process engineering, and task engineering (Smith & McKeen, 1993). Each form has a focus on engineering "organizational changes" of a certain nature and magnitude. Infrastructure engineering deals with executive management, process engineering concentrates on changing operational business process, and task engineering deals with job design and screen layout. This division implies the process of three operational levels when examining an organizational system: an organizational level, a process level and an individual level.

In this research, we used this three level division to help us take an in depth overview of the impact of mobile workforce solutions. Our proposition was that any implementation of "mobility" can be expected to penetrate an organization to its core functions and structures, so the units of analysis need to be similarly comprehensive: individuals, processes and the organization as a whole.

Within these three levels we further focused on specific issues. The literature in the field of mobile business shows that the introduction of mobile solutions in an organization reflect the character of the business at hand and the solution used (Barnes, 2003; Derballa & Pousttchi, 2004; Gebauer & Shaw, 2004; Harmon, 2002; Hoefling, 2003; Manzoni & Angehrn, 1998; Walker & Barnes, 2004). For our research, we abstracted the core aspects of an organization that will be directly affected by implementing mobile workforce solutions, see table 2.1. The detailed explanation of this is as follows.

Level	Issue Category	Why it is an issue
Organization	Workforce management Balance of work factors, such as optimal staff levels, anticipated workloads, and resource availability.	Workforce management is not a new issue, but by combining traditional methods with mobile applications, new capabilities will become feasible, e.g. tracking and controlling mobile workforces. These new capabilities allow companies to improve workload forecasting and resource scheduling directly.
	Organization structure The way organizations link workforces and the way to support their collaboration.	Mobile workforce solutions have a major influence on distributed work, and they create the possibility to link workforces together across locations to get a "virtual working" environment according to (Hoefling, 2003). Organizations have the opportunity to transform a virtual workforce into a functioning virtual organization by adopting appropriate structures, for example, decentralized, team-based and distributed structure etc.
	Knowledge management (KM) Networking and sharing corporate information, including data management, and information management	For the time being, the potential of KM is usually limited to stationary workplaces. This excludes a multiplicity of mobile workers, many of them in charge of knowledge-intensive activities. An organization's capabilities to support KM may be extended through the introduction of mobile technology usage. For an extensive discussion on the contributions of mobile technology for supporting KM in the different phases of the KM process i.e. knowledge retrieval, knowledge exchange and knowledge creation, we refer you to (Derballa & Pousttchi, 2004) and (Huysman & de Wit, 2004).
Process	Automation The use of computer systems and software to automate a process.	Processes can be completely automated, so no human intervention is required, or semi-automated, when some human intervention is required to make decisions or handle exceptions (Harmon, 2002). Mobile devices and applications can provide the "hardware" and "software" needed to trigger business process automation. Process automation is the primary function of current mobile workforce solutions. Examples: automated meter reading to save costs, a filed inspection data registration process.
	Alignment The creation of tighter coordination among the discrete business activities conducted by different work units.	Internal business process alignment is essential for successful mobile workforce solutions. The nature of work and job roles may be transformed by the mobile medium.
Individual	Capability The abilities of workforces when they execute tasks in the field based on certain supports.	Mobile solutions mainly have an influence on a workforce's mobility and reachability. Mobility refers to the level of geographic independence of mobile workforces, and reachability refers to their ability to be contacted despite mobility.
	Task The functionalities and scope of tasks attached to the job role.	Gebauer and Shaw (2004) adapt the concept of task/technology fit to account for the fact that mobile applications potentially cover a wide area of tasks. Their analysis suggests that it is important to ensure compatibility between the requirements of a task and the mobile capabilities of an application. For example, the requirement for accomplishing a task via (e.g.) standardized and personalized mobile applications.
	Acceptance Attitudes towards usage and intentions to use the technology.	The adoption of mobile technology has a direct influence on the human aspect of workforces, for example, on their working habits and work motivation. We refer you to (Liang, Xue, & Byrd, 2003; Venkatesh, Morris, Davis, & Davis, 2003) for an extensive discussion of this factor.

Table 2.1 Analysis framework for emerging issues

Workforce management is not a new idea, but combining traditional methods with mobile applications, will make new capabilities feasible, e.g. tracking and controlling mobile workforces.

Knowledge management (KM) is evolving into an increasingly eminent source of competitive advantage. However, for the time being, the potential of KM is usually limited to stationary workplaces. This excludes a multiplicity of mobile workers, many of them in charge of knowledge-intensive activities. Organizations' abilities to support KM may be extended through the introduction of mobile technology usage. For an extensive discussion on the contributions of mobile technology for supporting KM in the different phases of the KM process, i.e. knowledge retrieval, knowledge exchange and knowledge creation, we refer to (Derballa & Pousttchi, 2004) and (Huysman & de Wit, 2004).

Organizational structure The technical possibilities available change the way organizations work. Mobile workforce solutions have a major influence on distributed work, and they create the possibility to link workforces together across locations – i.e. "virtual working" according to (Hoefling, 2003). Organizations have the opportunity to transform a virtual workforce into a functioning virtual organization by adopting appropriate structures, for example, decentralized, team-based and distributed structure etc.

Business process automation refers to the use of computer systems and software to automate a process. Processes can be completely automated, so no human intervention is required, or semi-automated, when some human intervention is required to make decisions or handle exceptions (Harmon, 2002). Mobile devices and applications can be used to provide the "hardware" and "software" need to trigger business process automation, for example, a filed inspection data registration process. Process automation is the primary function of current mobile workforce solutions.

Business process alignment is the creation of better coordination among the discrete business activities conducted by different individuals, work groups, or organizations, so that an integrated business process is formed (Markus, 2002). As we have stated before, our focus is on business process alignment that take place within a single organization, when various engineering, supporting, and managing activities are synchronized into a new process, the internal business process alignment is essential for successful mobile workforce solution.

Capability, the capabilities of workforces to execute tasks in the field based on certain support(s), for example, the level of geographic independence of mobile workforces, and their ability to be contacted despite mobility.

Task, Gebauer and Shaw (2004) distinguish three types of tasks, i.e. operational, informational, and management tasks, based on (Davis & Olson, 1985) They further adapt the concept of task/technology fit to account for the fact that mobile applications potentially cover a wide area of tasks. Their analysis suggests the importance of ensuring compatibility between the requirements of a task and the mobile capabilities of an application.

Acceptance, the human factors of workforces, including their attitudes to the use of mobile technology, and their responses to aspects of (e.g.) work habit and work motivation.

Our proposition was that table 2.1 can be used as a framework to examine the issues of mobile workforce solutions and we therefore used this framework to analyze the two inductive case studies, aimed at achieving a comprehensive understanding of the issues involved when introducing mobility solutions in businesses.

Analysis framework for design approaches: unit of analysis for aspect 2
From our perspective, the achievements of mobile workforce solutions and business process redesign follow a certain design approach. A design approach is commonly understood to be a coherent set of activities, guidelines and techniques that can be used to structure, guide and improve a (complex) design process. Sol (1990) provides an analytical framework to describe a design approach, which is structured in terms of a way of thinking, a way of working, a way of modeling, and a way of controlling (see section 1.3). We adopted this "ways of" framework and used it to analyze the design approach in each of the inductive case studies. The main components of the "ways of" framework are summarized as follows:

- the way of thinking expresses the underlying philosophy; the perspective taken on the problem field is stated and underlying assumptions are made explicit. The way of thinking determines the ways of modeling, working and controlling. The way of thinking is often expressed in guidelines, rules of thumb, do's and don'ts, metaphors and design theories.
- the way of controlling, or the managerial method expresses the managerial aspects of a design approach.
- the way of working, or the working method, expresses the possibly compound tasks that must be carried out in the design process.
- the way of modeling refers to the modeling tasks and the use of modeling concepts that are suitable for modeling relevant aspects of the problem situation.

2.1.3 Case study strategy and method

Yin (2003) proposes four types of design strategies for cases studies: they are single-case (holistic) design, single-case (embedded) design, multiple-case (holistic) design, and multiple-case (embedded) design. In this study, we deployed the multiple-case (embedded) design strategy, illustrated in figure 2.2.

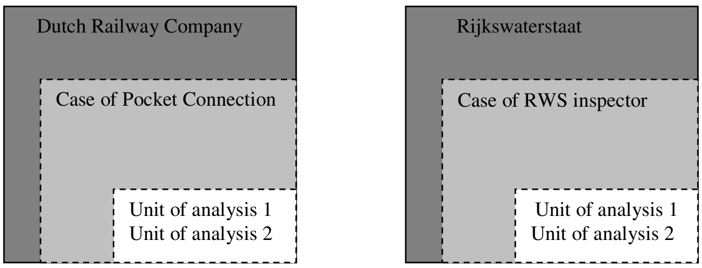

Figure 2.2 Illustration of multiple-case (embedded) design strategy

We had two main reasons for choosing this design strategy. One, we believe that the evidence from multiple cases is more compelling than that taken from a single case, and therefore the overall study will be more reliable. Following (Yin, 2003), we felt that two cases that "serve in a manner similar to multiple experiments, with similar results predicted explicitly at the outset of the investigation" were necessary and sufficient for this study. Two, as we identified two aspects for addressing the case study question, we wanted to examine both aspects. The two analysis units specified in section 2.1.2 were therefore applied in each case study.

Following the strategy mentioned, we can summarize the method of this study as shown in figure 2.3 (adapted from (Yin, 2003)).

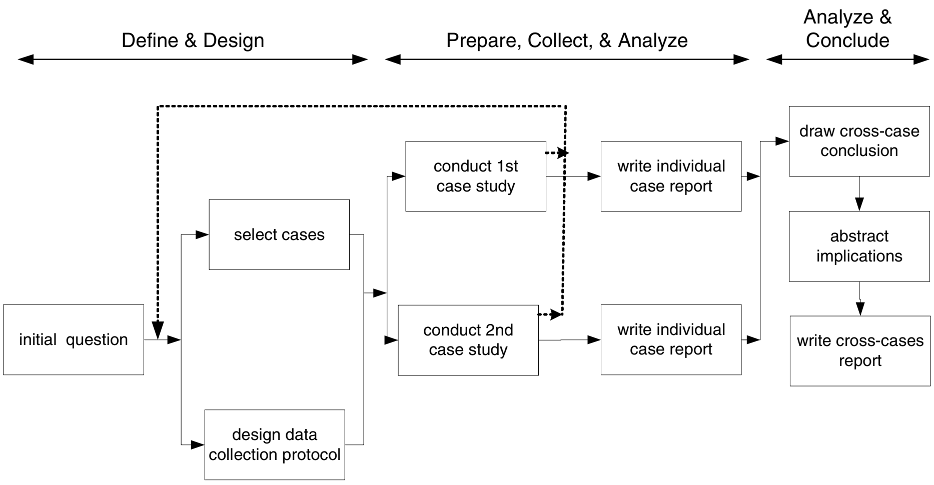

Figure 2.3 Case study method

We chose the "Railpockets connection" project and the "RWS inspection" project as the two cases met the following criteria (Yin, 1989): relation to the research topic, rationale for multiple-case design, power to access, and geographical location. The Railpockets connection project ran from 2002 to the end October 2004, and consisted of three phases: design, develop and roll out. The RWS inspection project concerned the design of a pilot solution, started in 2003 and executed in January 2004. We cooperated with the project teams directly involved in these projects as they could provide us with insight into the relevant issues during the projects.

The data collection was done using semi-structured interviews and a document study. The interview protocol is included in appendix 1. The document study provided us with good material which we used to prepare for the interviews. The insights gained during the interviews were used to direct a further document study. Any inconsistencies and questions arising during the analysis phase were discussed with the project team leaders. In total twelve interviews were carried out between October 2003 and March 2004. The interviewees were selected, taking into account their roles in the projects, and included business analysts/ICT professionals from LogicaCMG and the operation managers/ICT managers from the involved organizations. The instruments used while conducting the case studies are outlined in figure 2.4 below.

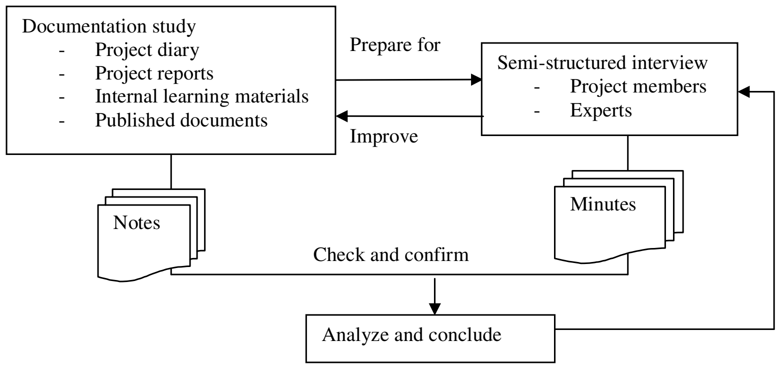

Figure 2.4 Use of instrument while conducting case study

2.2 Case one: Railpockets Connection

2.2.1 Background

The largest Dutch Railway company, Nederlandse Spoorwegen (NS), has continuous problems with providing its core capability, public transport. NS aims to provide relevant and timely information to its customers however it faces difficulties in managing its 10,000 strong mobile workforce maintaining a dynamic view of staff activities, and in distributing operational and travel information. Enabling efficient communication between mobile workers, called "frontliners" within NS, i.e. conductors, drivers, service personnel, and engineers, and supporting these frontliners in providing up-to-date information to railway passengers therefore become an important issue for NS.

Since 2000, all frontliners have been equipped with stand-alone Personal Digital Assistants (PDAs) called Railpockets which are used to provide a travel planner and reference information. This has released frontliners from the need to cope with complex paper versions of train schedules and manuals when dealing with a request for information. Besides providing information, the Railpocket is also used for registering daily occurrences such as delays, number of passengers per journey, ticket sales, incidents of aggressive behavior, damage reports etc. Train conductors uploaded the gathered information to central computers on a daily basis, via a PCMCIA memory card, so NS management are provided with the daily update on all information gathered by the frontliners.

Frontliners are also equipped with GSM phones for voice communication in emergencies. A special SMS application has been embedded in the GMS phones, which is capable of providing real time alerts on delays and scheduling. This has improved customer service and the cooperation between frontliners and back office staff. The situation at NS is summarized in table 2.2 below.

Tasks of frontliners	Mobile solution	Benefit
Registering daily delays Registering number of passengers per journey Registering ticket sales on the train Registering incidents of aggressive behavior Registering damage reports Providing travel planning Providing other information	 Railpocket	NS management is provided with the daily information gathered by the conductors Frontliners are released from paper versions of train schedules and manuals
Receiving delay alerts and up to date information on scheduling	 SMS	Improved customer service and cooperation between frontliners and back offices
Voice communication in emergency	GSM phone	Improved coordination in an emergency/delay situation

Table 2.2 The mobile workforce solution in NS as of 2001

2.2.2 Project

Mobile devices and technologies have advanced enormously since 2000. PDAs have evolved with the introduction of mobile data communication technologies like Bluetooth and GPRS - and these advancements have afforded the NS the opportunity to introduce online functionality to Railpockets, the *Railpockets Connection* solution, which may lead to more effective use of the communication means.

Project setup

The aim of the project was to enable the online component in the Railpocket to provide instant access to real time information about disruptions and changes to train schedules using the large display. When looking at return on investment and its long-term strategy, NS also noticed a need for the Railpocket Connection to support more business applications in the upcoming three to four years, e.g. the integration of electronic ticketing inspection.

As a train operation company, NS did not have sufficient knowledge on mobile technology and related solutions, hence turned to LogicaCMG for consultancy and implementation. The project team consisted of business analysts and ICT professionals from LogicaCMG, and operation managers and ICT managers from NS. They worked at NS headquarters to guarantee team working efficiency and coordination. The project's challenge was summarized in the question: How can the mobile online concept be leveraged to create more business applications towards an overall improvement of NS' business performance?

The project consisted of three phases: design, develop and roll out. When we conducted our study (winter 2003), the design part had been finished. Development was scheduled from spring of 2004, and was excluded from this study. Below, we will describe the design approach used in the design phase.

Design approach

The design approach used in this project is summarized in figure 2.5.

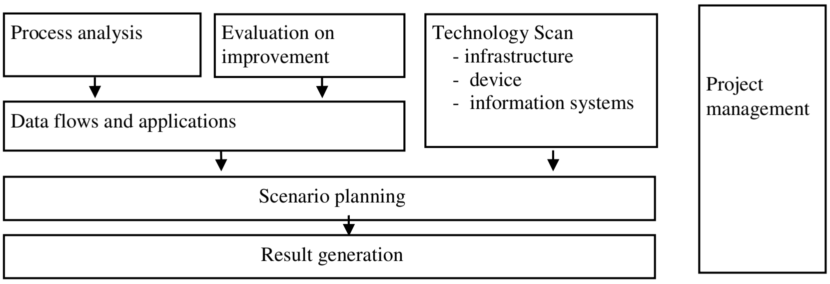

Figure 2.5 Design approach of Railpockets Connection case

Project management

All activities were coordinated under the project management paradigm. The team worked with frontliners, operation managers, and many other internal departments, e.g. the department of service management and travel information, the department of maintenance and repair, the department of internal communication, the department of traffic control, the department of station management and the ICT department.

Interviews and group meetings were the primary instruments used during the initial phase. Sample questions investigated were:

- What information is exchanged among frontliners at present?
- When does it happen, using which application, and for whom?
- When should voice communication be used and when should data communication be used?
- When is the information online and when is it offline?
- What is the quantity of the exchanged information, e.g. amount, frequency, importance, and capacity?
- What is the quality of use, e.g. ease of use and ergonomics?

Process analysis

The project team started with a process analysis that focused on structuring the primary work process of NS frontliners. A process-modeling package, ARIS (see http://www.ids-scheer.com/), was used to describe all processes and information flows. An example of the process model constructed for this project is shown in figure 2.6. During the process analysis, particular attention was paid to understanding what information was used or produced by frontliners at which moment.

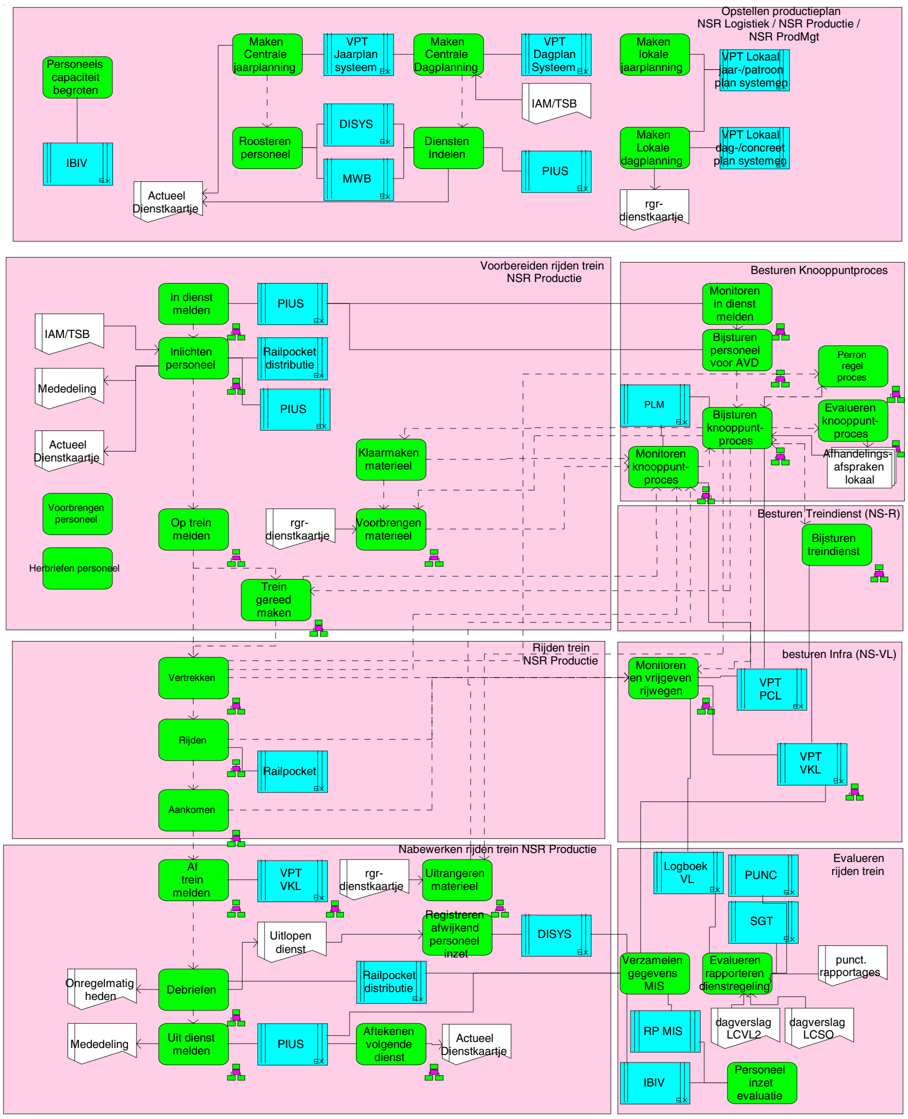

Figure 2.6 Process Models of Frontliners (source: Railpocket Connection Project Report by LogicaCMG)

Evaluation on improvement

The project team defined the concept "contact moment" as a concrete and structural moment in the business process when a frontliner works/communicates with the help of mobile support. Seventy-two contact moments were identified based on the process models. An evaluation of improvement was carried out for these contact moments and eighteen contact moments were found to be improved as a result of introducing Railpocket Connection.

Data flows and applications
Process analysis was used to structure the data flows, and this formed the basis for designing applications. To support the application design, four aspects were further examined for each of 18 contact moments- the targets of the improvement. The four aspects were:

- process: When does the contact moment happen in the entire process?
- information: What information is communicated at this moment?
- communication: In which form is the communication conducted?
- support: What are the support facilitates used for the communication?

Technology scan
A technology scan was conducted in parallel with the aforementioned activities, consisting of an evaluation of the possibilities of wireless communication, GPRS, WLAN, Bluetooth, and the necessary hardware, GSM handset, and PDA, taking into account the specifics of the target group, i.e. a desk-less workforce working in moving trains.

Scenario planning
The next step was to formulate scenarios, including working prototypes, and compile business cases for the scenarios. Three scenarios were formulated based on the possible mobile infrastructures and information systems, and the business cases were completed for each scenario in terms of the enabled applications. A proposed platform and a number of applications were generated by analyzing the cost, quality, efficiency, and other impacts.

Result overview
The analysis showed that most information used by NS frontliners was still static or semi-static, meaning that only actual information needed to be accessed online. So the applications were based on the “fat client on a thin wire principal”, where all the static data is held on the Railpocket and only changes taking place during the working day are accessed using online communication. Besides migrating current applications to a new platform, the solution also included four new business applications.

- Application 1: a map of The Netherlands where disrupted routes are displayed as a red line. Selecting the red line allows detailed information about the disruption to be retrieved from the back office and displayed to the user.
- Application 2: an overview of actual departures per railway station is displayed, where changes to the schedule are highlighted. As the large displays commonly present in stations are used to provide actual information to passengers, the need was highlighted to use the same information source in the back office without adding intermediate systems.
- Application 3: all information is personalized for specific employees, i.e. context driven. Based on an employee’s personal schedule the Railpocket knows where the employee is and which tasks he or she is performing. Information targeted at these activities is presented to the user.
- Application 4: online information on the maintenance of individual trains and registration of defective parts is provided. Using this application, the maintenance department can be alerted about the status/defects of a train before it rolls into a workshop at night. This allows maintenance to be planned, repair crews can be informed of defects and the crew can bring along the correct spare parts required to deal with a defect.

The project team proposed an open platform for current and potential functionalities by choosing standards like PDA with Windows Mobile Operating System, GPRS handsets and Bluetooth technology, see figure 2.7. A new type of PDA (HP iPAQ) was adopted, which can be accessed via Bluetooth/GPRS and receive information alerts via SMS.

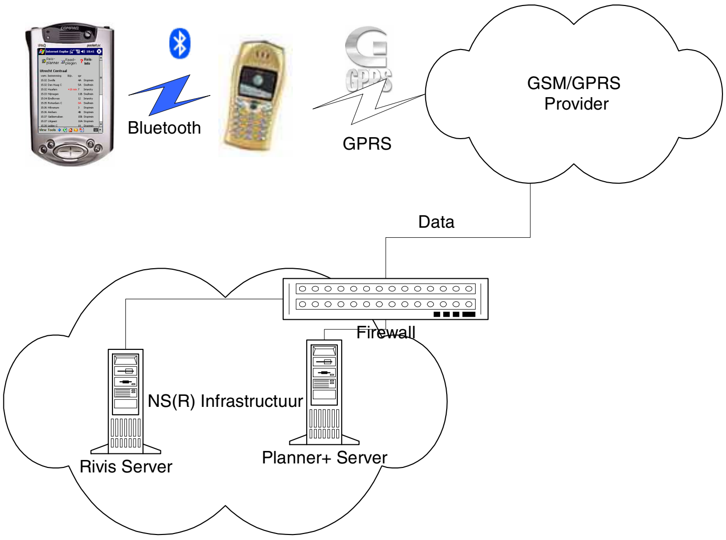

Figure 2.7 Railpockets Connection based on Bluetooth/GPRS

2.2.3 Case analysis

In this section, we apply two units of analysis in the NS Railpockets Connection case. We first deal with the organizational issues of Railpockets Connection, see table 2.3. We then look at the design approach of Railpockets Connection using the "ways of" framework.

Analysis on emerging issues

We applied the first unit of analysis to evaluate the issues of the solution in this case, see table 2.3.

	Issue	Railpockets connection
Organization	Workforce management	Tracking mobile workforces is feasible in the new platform. The management better understands employees' work status and performance. The management team was aware of the need for new policies for the personnel being "monitored".
	Organization structure	NS has complex internal business process, and it is an information-intensive, highly distributed, and time critical organization. Its core business is operational processes in a routine but dynamic environment. The coordinating mechanism is not radically changed by the solution.
	Knowledge management	Conductors have instance access to actual departures, which is the same as the information known in the back office. Thus helps to prevent inconsistent information being given to passengers.
Process	Automation	The new solution enables conductors to report train defects to the maintenance department through a PDA instead of using a registration sheet, which makes the reporting process more efficient and simple.
	Alignment	Application 4 aligns inspection processes and maintenance processes. The team viewed the application to be a result of studying collaboration among the intra organizational business processes. They concluded it was important to expand perspectives when discovering process alignment, and to not be constrained in one process horizontally, but to focus on the relations and interdependencies between processes vertically.
Individual	Capability	Conductors' mobility and reachablity are improved because of the online function of the PDA.
	Task	Conductors' main tasks changed from "check tickets" to "inform passengers".
	Acceptance	The lack of a full size keyboard and the relatively small display were identified as the two shortcomings of the new PDA. In order to address these concerns, the design of the user interface received special attention. NS also recognized that whilst the recipients of Railpockets wouldn't always be technically minded, user adoption is extremely important.

Table 2.3 Issue Analysis for Railpocket Connection case

Analysis on design approach

Way of thinking

It was observed that the initial organization the NS assigned the leadership of the project to its internal IT department. Throughout the project, the project leader bore an IT design approach in mind, i.e. the waterfall approach in this case. However, the IT department had little insight into the low-level business problems, faced by the frontliners and understood only by their operation department.

Way of working

We have summarized all the design activities in figure 2.8. Our observation is that the project team spent most of their efforts on the activities in the shaded area, this may be a result of their "way of thinking". These parts are important because they have direct influence on return on investment (ROI), security, reliability, etc. These are crucial for the approval of the project and were also primary concerns of the IT department which led the project.

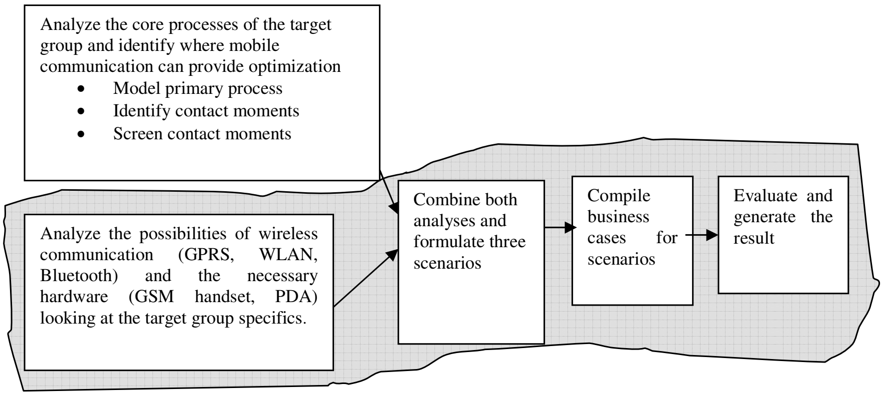

Figure 2.8 Illustration of way of working for Railpocket Connection

Way of modeling

The business analysts of the project team explained "in theory, we should start to capture NS's current business process by modeling because it will give us insight into their operation activities and it is important for us to identify potential applications to be integrated into Railpocket Connection. But we did not have time to do this, modeling is too time consuming, therefore it is very expensive, and NS did not want to pay for that. In the end only primary processes around "frontliners" were modeled."

The purpose of process modeling in this project was set to help describing potential, processes and functionalities, changes. To describe the process changes, a modeling tool-ARIS, was used. ARIS is a commercialized process-modeling tool, which is often used by LogicaCMG's business analysts. ARIS is used to represent the architecture of integrated information systems, which distinguishes four views: organization view, data view, function view, and control view. The latter is used to establish the relationships between the components.

Scenario planning can also be regarded as a modeling method. However, when we examined the scenario planning report of the project, we found that the project team had misused the word scenario, it was indeed an evaluation report of three technical solutions in terms of cost and benefit.

Way of controlling

The project was controlled under a "project management" paradigm. Deadlines and milestones were broadly used to control the progress of the project.

2.3.4 Discussion

Character of the organization

NS has complex internal business process, and it is an information intensive, distributed, highly mobile, and time critical organization. Its core business is about operational processes in a routine but dynamic environment.

Joint team
In this project, it was clear that the NS was the problem owner. NS management had seen that there was insufficient support of the frontliners' work, which in turn caused problems in customer service, process operation and management. NS management was aware of the development of mobile technology and they wished to be prepared to utilize the advantages for their business. Therefore, the NS initiated the investigation of the solutions.

Since NS had limited knowledge of mobile technology and solution, it needed a solution provider who had expertise in this field. It turned to LogicaCMG for consultancy and implementation. Therefore, the project team consisted of people from both organizations, business analysts and ICT professionals from LogicaCMG, and operation managers and ICT managers from NS.

This cooperation mechanism proved to be necessary and effective according to the project team. It bridged the mobile expertise and practical knowledge holder, and enabled their joint work to support the key decision-making on whether remote communication was really necessary. The project was a kind of "matching" process: matching the technology offers and business needs. The process required good support on how to sort out the requirements for matching and what the criteria were for the decision-making.

Bottom-up discovery
Because the main targets in this project were NS frontliners and their work processes, the primary task for the project team at the beginning was to discover the current business processes around frontliners. Generally speaking, there are two kinds of discovery approaches:

- the top-down discovery approach, which typically begins with the organization chart. It lists the responsibilities of each department in the organization and identifies the high-level processes that support these responsibilities.
- the bottom-up approach begins by interviewing employees about day-to-day activities they perform and attempts to integrate this local information into coherent end-to-end processes.

The top-down discovery approach proved not to be applicable in this case according the process analyst for the project. This was further explained during an interview: "What we needed to discover were processes right at a very low level of NS operation hierarchy. However the process knowledge is not explicit and centralized in NS: it is to a large organization and NS' end-to-end processes are not known accurately or in detail. For instance, NS could not offer a workflow model of the frontliners. What it offered was just an organizational tree – off course, that was not sufficient for us."

So the project team adopted a bottom-up discovery approach in the process analysis phase. The main problem that occurred with this approach was that, summarized by another project team member, "the interviews allowed us to get accurate information, but you can easily get lost in the details, failing to see the forest for the trees. It is difficult to control our interviews… many times they go out of control and you have to spend considerable time on drawing conclusions about the information afterwards."

Contact moments
Though the business analysts were aware of the importance of business processes discovery, they gave up the attempt to capture the full picture of the current-state business processes. This was because, one they knew (based on their experience), it was not a simple task and they could not finish within a short time; two, it was not supported financially by the NS management because the management thought it was out of the scale of the project.

As an alternative, the project team chose to capture “contact moments” instead of business processes during their design approach. The concept of “contact moment” was invented as an intermediary for assisting their understanding of “process”. The following arguments support how they formulated this concept.

- The mobile application created a new channel for the mobile workforce, via which some information becomes available.
- The mobile workforce needed to choose channels in a specific situation.
- The choice will not always be for the mobile application, it may also be for non-mobile channels.
- The mobile applications enabled the “mobile workforce” to have direct or indirect contact with NS organization.
- The contact meant “information exchange” taking place via (or not via) information systems.
- Some contacts were important for the mobile workforce to fulfill the service framework to the customers. Additionally, some contacts were made for non-customer-related tasks.

Alignment of business processes

The application 4, “online information on the current maintenance of individual trains and registration of defective parts”, aligns the maintenance processes. Using this application, the maintenance organization can be alerted about the status/defects of a train before it rolls into the workshop at night. Using this feature, maintenance can be planned, repair crews can be informed of defects and the crew can bring along correct spare parts in advance, also see figure 2.9.

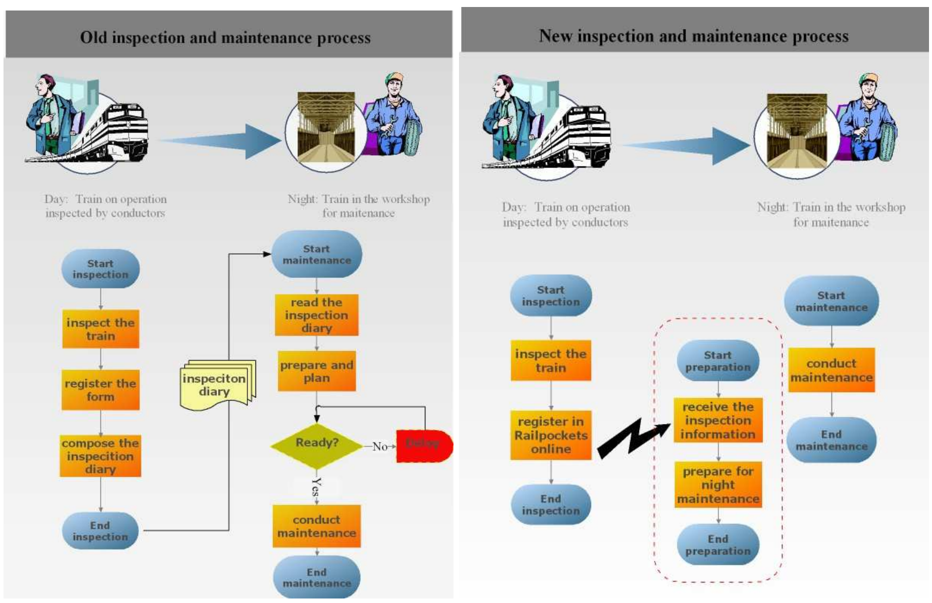

Figure 2.9 Illustration of the alignment business process in NS

The application 4 was favored by the NS management, and the project team also thought it was an innovative design. The team viewed the achievement to be a result of studying the internal business processes of the organization. They conclude it was important to expand perspectives when discovering process alignments, and not to be constrained in one process horizontally, but to focus on the relations and interdependency between processes vertically.

Modeling tool

"Choosing a tool is not an issue; from my view, any tool may produce similar results," one process analyst in the project, said during an interview "ARIS is not so friendly to me in that it is very strict in "input", "output"… and it has no specialized support for modeling "mobility" of a process. Our ARIS model is static since there seems no need for it to be dynamic in our case… the model helped us to conceptualize the situation". She added, "there are no ways to reduce the time required to collect data—you always need to talk, interview people, for instance the frontliners in NS project. But components, building blocks can be used to reduce the modeling time, which will be of use and value in practice. If there is a simulation suite that targets at a specific mobile workforce, I would like to test and use."

Measurement of improvement

The potential value of a new mobile workforce solution has come under considerable discussion; but the question was how to evaluate and measure the value of design result for NS, e.g. how much will be gained in the scenario and what will the business process look like. These questions proved to be very important for the decision makers from NS management when the project team presented the design results for approval. However, there were no efforts incorporated in the design approach to address those questions. One of the business analysts explained further: "In scenario planning, we easily sketch out the necessary cost for option; but we cannot effectively analyze the improvement of the new processes in terms of efficiency, productivity and so on because we lack sufficient data and tools."

2.3 Case two: RWS Inspection

2.3.1 Background

Rijkswaterstaat (RWS) is part of the Dutch name "Ministry of Transport, Public Works and Water Management". RWS has five main departments, each of which has 3-5 sub-departments. This project was targeted at the sub-department "highways" which is responsible for inspecting the national highway systems. Inspection tasks are allocated per geographical region. This results in decentralized data collection, and RWS has had problems with integrating and updating their central database of highway inspections. RWS wants to standardize the inspection work to improve the accuracy and efficiency of data collection and management.

Driving along the highway of the regions, the inspectors have two main tasks: report the accidents and report the state of the highway, e.g. report damage caused by a traffic accident, obstacles caused by the bodies of dead wild animals etc. The inspectors write down inspection details and make a report at the end of a day; the data are sent weekly to a central department, where all data are entered into a database; the central database is updated monthly. The identified problems were: data are not reported in time, the delay for entry is big; double entry makes the work less efficient; nobody has an overview of the data analysis and thus no action is taken, e.g. wild animals are often found on highways passing through forests but no fence is built to prevent the frequent accidents.

2.3.2 Project

In September 2003, the highway inspection department in the region of Apeldoorn started to think about possible improvements in its inspection work.

Project setup

At the time, most inspection activities were done using pen and paper to collect field data. The handwritten data had to be typed into a report every weekend. Typically, the inspectors were expected to record the inspection information, for instance type of incident and location. This occupied most of the inspectors' time when they were carrying out field inspections. Traditionally, inspectors often provided location information coupled with comments to refer specific conditions, e.g. 100 meters away from exit 4 of highway A20. The ambiguous nature of the location information often caused problems for the cooperative administration and later data retrieval. Eliminating these problems became the most important reason behind the idea of using location based services.

Design approach

The objective was to test how far the highway inspection work processes could be carried out with the help of a mobile GIS application. To meet this objective, a functional design was described and on the basis of this an application was developed. The application was tested in practice over a three-week period by different inspectors, covering their various day-to-day functional issues. The design approach is summarized in figure 2.10:

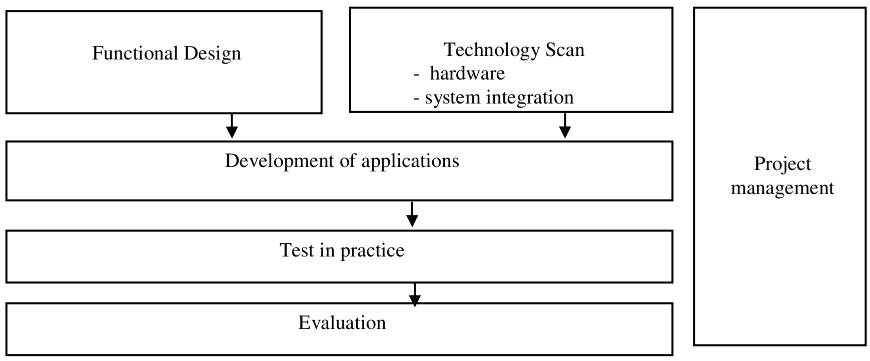

Figure 2.10 Design approach of Railpockets Connection case

Functional design

The project focused on identifying the needed improvements for current work processes. Two types of work processes done by inspectors were considered in the functional design of the application, one, work processes in the field, and two, processes carried out at a central location/office. The two processes are illustrated in figure 2.11.

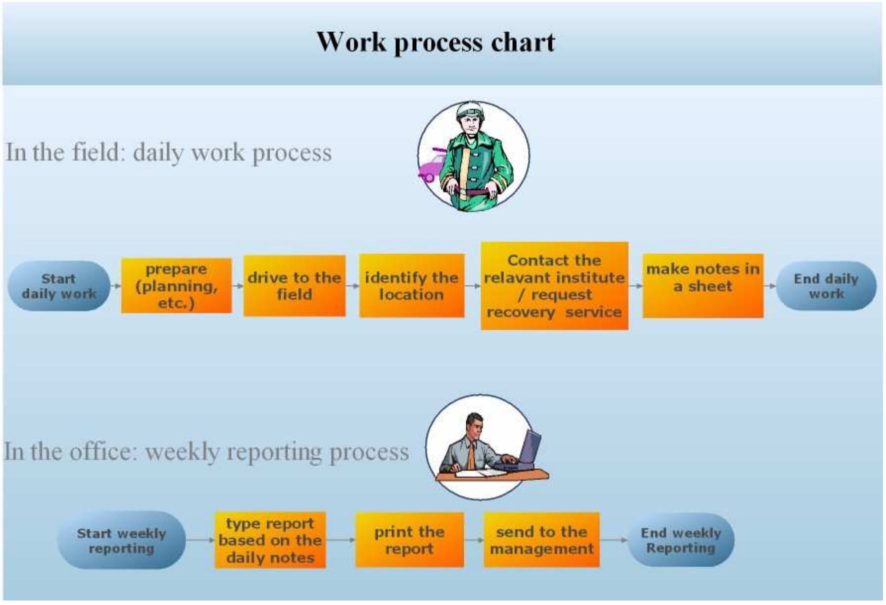

Figure 2.11 Inspectors' work process in RWS

A number of function requirements were elicited in a sense of discussions with inspectors and the management team. These are listed below.

- More accurate location information. This should enable inspectors to identify accurate location information.
- Better information support. This should enable inspectors to access the historical inspection record at a point of need.
- Rapid communication of information between inspectors and the RWS' organizational systems. This will allow information gathered by inspectors to be utilized by other functions in the administration chain without delay.
- Improved quality of planning. This should facilitate job planning; especially the planning of collaborative work between inspectors.
- Improved the productivity of an inspector. Automation of certain activities should produce improvements in productivity.
- Capabilities for efficient driving. Since the inspectors spend most of their time driving, navigation support is needed to enable them to follow a planned inspection route easily.
- Time savings in the processing of inspection notes. This should reduce the time inspectors spend on reporting, note: many inspectors do not like to type a report weekly.
- More effective management of inspectors. This should allow the administration to know the locations of inspectors at all times and improve time management for inspectors.
- Personalization. The system should be able to filter relevant information and tailor services to the needs of particular users, e.g. provide personalized information).

Technology Scan
Regarding the function requirements, the project team came to two conclusions. Firstly, mobile geographic information systems (GIS) applications may be suitable for application in the highway inspection work processes. Secondly, real-time data access is rarely required in a field environment.

Following on the first conclusion, the team chose to use the HP iPAQ to use as a handheld device taking into account it's clarity for daylight viewing and its ability to configure various storage media for map files used in conjunction with GIS applications. GIS is wildly used by a variety of public and private agencies to store and manipulate data about specific locations in specific areas. Coordinates data forms the basis for GIS applications. A GPS (global position system) unit connected with GIS can be used to determine locations. The project chose to couple a Pocket PC GPS receiver to the HP iPAQ.

The project team then developed RWS application-specific software and data. The handheld device was designed to synchronize data with the host application, store it locally to be used and updated, and then to return the modified data to the host. In most cases the synchronization would occur at the start and end of a user's shift, but the timeframe could be shorter, as appropriate to the application.

The main benefits of a "thick solution" are, for instance:

- an ability to keep working when there is no coverage
- much faster information processing of data from the field
- a lower cost of operation – no cost for wireless data transmission over the network
- maintaining data integrity by using a database on the device

The project team also noticed some issues with respect to the chosen "thick solution", for instance:

- there is only access to data downloaded by the last synchronization
- a large data store is needed on a mobile device for all downloaded data, whether required by a specific mobile device or not – depending on the capabilities of the synchronization software
- all mobile devices must interact directly with the host server to synchronize data, which could cause data integrity problems if communications are lost while the device is updating the host

Development of applications
The map application and other data entry forms were developed in ArcPad, a popular commercialized GIS development platform, for use on the iPAQ. The screenshots of some applications are presented in figure 2.12. We will not discuss every application in detail, however we will give two examples.

- The Inspections form is where the inspectors create the inspection record. This screen allows the inspector to choose the type of inspection, defaults to the current date, and has "Yes/No" checkboxes to capture data specific to RWS. To create an inspection record, the inspector taps the "Perform an Inspection" button, and edits the appropriate fields.
- Tapping "View Past Inspections" from the Inspections form brings up three forms that display data from previous inspections. The History form allows the inspector to view past inspection records of the same area. This is a read-only form that is available to the inspector as reference data.

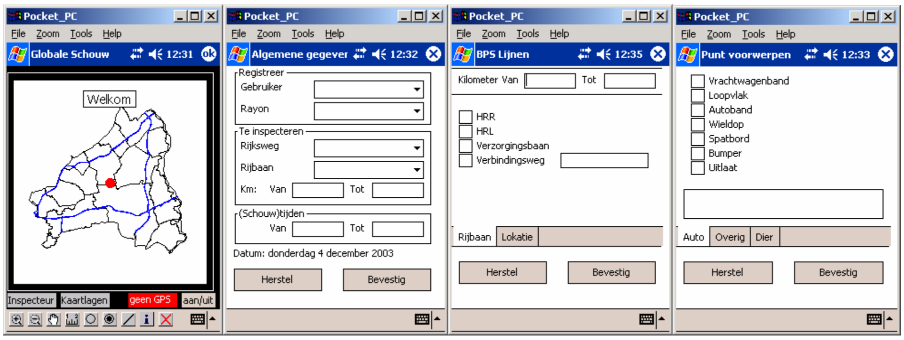

Figure 2.12 Screenshots of applications

Test in practice

The developed applications were loaded into several pocket PCs for a pilot test. A number of inspectors participated in the three-week long test. In starting the application, the inspector was given a pocket PC with an 'empty' background consisting of the control area of the Apeldoorn, the Hectometre boards map, the Municipal boundary map, and the current GPS position. Before starting an inspection, the inspector recorded his personal information, and then drove along the part of the road to be inspected using the maps and GPS. If the inspector came across an irregularity, he plotted the position of the irregularity on the background map, using the GPS position and map. At first, he had to register the GPS position with the plotted position. After that, the inspector could send administrative data of the plotted inspection in an easy and fast way. The inspector could retrieve or change the information relating to the plotted inspection and the work carried out earlier in the same day. When the inspector got back to the office, he synchronized his inspection records with the PC.

After an inspector has carried out the inspections and synchronized his Pocket PC with the back office, the highway inspection result can be displayed on the map page. Using the GIS application, a GIS-based analysis of the inspection can be made. Administrative and geographic (position on the map) data of the inspection carried out earlier can easily be searched for and retrieved. The displayed maps can then be plotted. The retrieved inspection information can also be modified, and from the retrieved inspections, standard reports can be printed.

Evaluation

The important results of the practical test and recommendations for possible follow-up of the Mobile General Inspection application were described in an evaluation report.

- The inspectors and their coordinators were very enthusiastic over the use of the developed application as in the office and in the field.
- The application was simple to understand and thus fast to learn. Thus there was no expensive/long training necessary for users.
- All data entries were digitalized so that the inspection report could be generated easily. Through that function, inspectors could save a lot of time in the office and they could spend more time in the field.
- Since road information and other geographic information were integrated, the registration applications had become very "smart" and friendly.

- During the test, the performance of hardware, i.e. Pocket PC, GPS receiver, and PC, was satisfactory. Especially at night, GPS provides considerable added value.
- Data management and analysis was faster and easier with the GIS. Integrating GIS into the system stimulated a uniform manner for application data and thus brought advantages for data management.
- Broader data accessibility and more efficient use of data were possible. The opportunity was provided to develop more applications to support an inspector's daily work and RWS' management activities.

The time saved on the inspector's work processes was evaluated after the pilot, see table 2.4.

	Old situation	**Min**	**New situation**	**Min**
Start	The inspector chooses a route to inspect based on his planning and knowledge.	30	The inspector checks his route on his PDA	1
Inspect	Write down the location of an incident	1	Click the location of the incident in the PDA	1
	Contact the relevant institute and request recovery/disposal services	30	Contact the relevant institute and request recovery/disposal services	30
	Write notes in a sheet	10	Fill in the electronic form using the user-friendly interface on the PDA.	3
End	Type a standard work report based on the daily notes once a week.	120	Put the PDA in cradle and upload all inspection data to the information system	2
	Print a report and hand in.	8	No longer necessary.	0

Table 2.4 Time saving of inspection process by using the solution

Result overview

The GIS-based pocket PC applications provide highway inspectors with related information at the inspection site. The GIS application allowed the inspectors to view the inspection route on a graphic map and to verify the location using integrated GPS. Upon synchronization with the desktop PC at the office, the inspector could provide the collected data to the administration in an electronic form thus eliminating the need for a paper report and the customary data re-entry done by administrative staff. Elimination of the paper reports also included the elimination of time spent filing, copying and archiving which is normally associated with paper reports.

Collaborative work planning was improved by the solution because the route planning information becomes transparent: it is shared and shown on the map page through daily updating (download). It is easy to know for each inspector that who is inspecting which (part of) route and which route has been inspected earlier (by retrieving history record).

An employee trace and tracking function was not achieved "real timely" in the project, given that the "thick" solution does not support real time data transmission between field and central office. However the project team has developed a smart application to record an inspector's location and time regularly during work, and this information is uploaded into a database with daily synchronization. Using this database, management can keep track of its employees' work and performance.

2.3.3. Case analysis

Analysis on relevant issues

We applied the first unit of analysis to evaluate the issues of the solution in this case, see table 2.5.

	Issue	RWS inspection
Organization	Workforce management	Employee tracking function is not achieved "real time" in the project, since the current solution does not support real time data transmission between field and central office. The project team has developed an application to record an inspector's location and time regularly during work, and this information is uploaded daily into a database.
	Organization structure	Collaborative work planning is improved by the solution, because the route planning information becomes transparent: it is shared and shown on the map page using daily updating (download). It is easy to know, for each inspector, who is inspecting which route and which route was inspected earlier.
	Knowledge management	Integrating GIS into the system has stimulated the use of uniform application data and thus brought advantages for data management. Data analysis becomes fast and easier with the GIS. Broader data accessibility and more efficient use of data become possible. It provides the opportunity to develop more applications to support the inspector's daily work and RWS' management activities.
Process	Automation	Registration process becomes "smart" and friendly because an inspector automatically receives accurate location information with all the relative road/geographic information integrated. The inspection report can also be generated easily, saving inspectors can save a lot of time.
	Alignment	Inspection information collection, distribution and administration processes are aligned much better than before. The inspector can provide the collected data to the administration in electronic form by synchronizing the data with a desktop PC at the office. This eliminates the paper report and the customary data re-entry process done by the administrative staff. Elimination of the paper reports also includes saving time spent on filing, copying and archiving paper reports.
Individual	Capability	The GIS based application allows the inspectors to view the inspection route on a map and verify the location using integrated GPS. The history of inspection site information can now be retrieved.
	Task	There is evidence to show that the inspector's job role has changed.
	Acceptance	The inspectors and their coordinators gave a very enthusiastic reception to the developed application both for field use and office work. The application is simple to understand and thus fast to learn. So there is no need for expensive/long training time before use. The performance of hardware, i.e. Pocket PC, GPS receiver, and PC was also satisfying, especially during the night, GPS provides lots added value.

Table 2.5 Analysis on impacts

Analysis on design approach

Way of thinking

We noticed that the project started with a clear goal – it was not to analyze, but to test how far the business processes could be supported by use of the GIS application. This was different from the last case, in which, the main efforts lay in analysis. The goal on the one hand implies the RWS is interested in the potential value of GIS, on the other hand it reveals the "way of thinking" of the project initiator: taking up a mobile solution quite early without a clear estimation of the success condition and ultimate value creation. This way of thinking may represent a general attitude towards mobile projects found in many organizations.

Way of working and Way of controlling
The way of working and controlling are similar to the NS case. The project team paid most attention to the technology scan and application development. The functional design was not thought to be difficult given the fact that the work processes considered were rather simple. There were few actors involved in the process, which also made interviews and group meeting easier. The project management paradigm was considered successful in this case.

Way of modeling
In this project, the application demo was developed to model the solution, which is a modeling method that has been broadly used in many mobile solution projects. In the demo, it is common to present only the application layout, without the underlying data support. There are commercial packages available to facilitate fast development of mobile application demos. It is an effective, efficient and economic way to start an application design. Feedback from test users can then be used to support the improvement of the overall usability and usefulness.

2.3.5 Discussion

This solution was used as an enabler for standardizing the inspection process, with a contribution to work efficiency, data management, and inspector administration. Mobile workforces' activities traditionally have been very difficult to analyze, track and manage in RWS. Though we did not look at the technology aspect in depth, it was clear that mobile technology played an important role in developing the solution in this project. Using mobile communication via multiple mediums, management now has the ability to support providing information to inspectors. Inspectors can access the work histories, and other important data.

We also noticed that the Pocket PC, GPS and the "thick" mobile solution have been available for many years. The question was why they were not adopted in RWS? A major reason for that could be "fear" at RWS about the change management: they had little experience in engineering the new business process for the mobile solution. It may also have been the common "fear" from the management perspective in today's mobile businesses revolution. Another fact could not be ignored is that RWS wanted to invest in the "pilot" project. This implied their attitude towards "adaptive learning" in the context of mobile solutions, led to their adoption of this "experimental" approach.

2.4 Implications and requirements

2.4.1 Implications for the design approach

Comparing the RWS case to the NS case, we found there were many similarities between the two solutions in terms of their impacts on organization, business process and individuals (see tables 2.3 and 2.5). This is because the work processes that both solutions target share the same nature: they are distributed. We gained empirical evidence from the two cases. Before describing it in detail, we summarize some characteristics of the two cases in table 2.6.

	NS	RWS
Stage	Analysis	Pilot
Target group / process	Many functionalities, complex processes	Few functionalities, simple process
Initiator	Central management	Local department
Type of organization	Public transport/full distributed work environment	Government inspection/ field work
Project cooperation	Joint (problem owner & vendor)	Joint (problem owner & vendor)
Modeling method	ARIS	Demo
Control mechanism	IT project	IT project
Mobile Solution type[8]	Online	Offline (synchronization)
Service type	Comprehensive services	Location based service

Table 2.6 Characteristics of two cases

Studying the "issues" based on our first unit of analysis, we concluded that mobile workforce solutions have direct impacts on many work related aspects, but they do not radically change the organizational structure and business processes within a company today. At present, mobile workforce solutions basically support the automation of existing and traditional business processes, for instance, the transition from paper-based processes. The case studies do not show that innovative businesses processes are created by using mobile services. The power of "mobile services" has not been fully explored. There is surely a potential for organizations to engineer "mobilization" further. We derived the following statement from results of the case studies: "Developing a mobile workforce solution is a complex task, especially considering its implementation. The creation of radical change of business processes calls for an appropriate engineering approach."

Applying our second unit of analysis, we observed that many organizations have noticed issues in operating and managing their mobile workforces. They have further realized the opportunities provided by the fast developing mobile technologies, there are a number of successful cases available in the market. Several conclusions related to the design approach can be made.

Two main steps in the design approach

Studying the design approaches of the cases, we concluded there are two main steps in mobile workforce solution design: the first step is to understand the way that mobile workforce solutions create business value; the next step is to understand the different types of mobile computing and mobile infrastructure available today. We also found that in practice the two steps are carried out by different people, i.e. business analyst and ICT professional. Consistence between two the steps is critical to maintain. The question is how to guarantee the cohesion of the two steps.

Multi actor system

In the NS case, we discussed the fact that, since NS management has little detailed knowledge on the end-to-end processes, one of the challenges for the project team was to discover the work processes of frontliners in detail. The discovery process is complex because it has to deal with a multi-actor system: a number of internal or external personnel and departments which are directly or indirectly relevant. For example, frontliners, operation managers, the department of service

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8 According to Kalakota and Robinson (2002), online means there is a real-time live Internet connection. Offline could be understood as that the device runs self-contained programs but is not connected to the Internet, which can interface with other devices and networks through wired synchronization.

management and travel information, the department of maintenance and repair, the department of internal communication, the department of traffic control, the department of station management and the ICT department. This implies a need for a systemic approach to stimulate and support the participation of involved actors.

Dynamics of the project

We have observed the corporate dynamics caused by the changing mobile technology. In the past 10 years, NS has been making efforts to support its mobile workforce. Looking back, we see that technology is always the enabler to change an NS frontliner's way of working, e.g. from Railpockets to Railpockets Connections. Therefore, there is a need for continuous improvement on the efficient and innovative execution of the activities of frontliners. It may require a kind of "process management" paradigm (de Bruijn, ten Heuvelhof, & Veld, 2002) instead of "project management" paradigm to control the design approach.

The dynamics caused by changing mobile technology also imply a need for flexibility and scalability of a design result. In the NS case, the design phase ended with an open platform for *current and future* applications, which shows NS' awareness of a need to cope with new mobile technologies and business requirements, for instance, mobile ticketing.

Process modeling

During the study, we noticed in practice that two perspectives can be distinguished on Business Process Modeling. First, business analysts talk about Business Process Analysis and Modeling, and focus on business-oriented modeling, e.g. Actor/Tasks analysis and the workflow modeling. Graphic presentation is the easiest and most flexible way of modeling; and in most cases the model is static.

Secondly, IT professionals focus on modeling with technical implication such as software development, e.g. developing the specific application for mobile workforces to automate their operation, and the information system integration, e.g. integrating the ERP system to the mobile channels. To date, many software development packages and information system design packages provide the function of "process modeling", for instance "software development" oriented process modeling tool RUP (Rational Unified Process, IBM), and the aforementioned "ARIS", which is particularly useful for an ERP system design such as SAP.

Problems in business process modeling caused by the "two perspectives" are:

- disruption between business logic and technical implementation – missing methodology
- no re-use of process knowledge
- business owner and IT expert do not speak the same language, do not share the same concepts of processes or use the same tools

2.4.2 Implications for practice

The results of these case studies confirmed that the fact that mobile technology is maturing, but mobile business applications are still in the early stage. Companies seem to have put all their efforts into relatively simple and primitive mobile solutions. Hence, the power of the "mobile service" has not yet been explored for solutions that basically support the automation of existing and traditional business processes. Good examples of enterprises that are using the mobile service to create new and innovative business processes, i.e., business transformation, are rare.

We also found that organizations, even though they take up mobile solution quite early, have difficulties in realizing strategic alignment, business transformation, and business process redesign.

A main reason could be that "too much attention has been paid to commercially available and proven technologies and applications and, unfortunately, too little attention has been paid to the commercial conditions for success and, ultimately, value creation and competitiveness" (Christensen & Methlie, 2003). Apparently, it is more convenient to focus on readily available software and hardware than to ask question about what creative and innovative initiatives one could take; likewise, it can be argued that politicians and policy makers have been equally concerned about technological issues, e.g., convergence, security, authentication, international standards, bandwidth and other issues related to ICT infrastructures (Christensen & Methlie, 2003).

Some other implications of this study are:

- in both case studies, the client organizations both hold the awareness of process optimization as one of their objective during the project setup, and the solution provider claims its approach is "business process driven".
- technologies supporting mobility makes an important contribution for process engineering. These technologies cover many, from GPRS to GIS, PDA , GPS, as seen from our case studies.
- the identification of opportunities for "mobility" is increasingly becoming a core issue for many companies. Through the case studies, we got an opportunity to approach many other organizations. We observed that many of them were investigating or preparing to investigate mobilization opportunities, from banks (e.g. ING), to insurance companies (e.g. National Netherlands), to logistic companies (e.g. TPG), to utility companies (e.g. Eneco), to manufacture companies (e.g. Philips) etc.
- the barriers for the adoption of mobile solutions in organizations are not to be found the technology challenges, like network integration, device management, routine support and maintenance. This is no longer a serious issue given the fact that hundreds of vendors, examples include Aventeon, iAnywhere, Symbol, and Xybernaut, are making efforts to take those challenges. Many packages and tools are available to help people deploy enterprise mobility in the current market.
- the biggest challenge for many projects is not to find matured mobile technologies (see above), but to fit them into their business operation. The real challenge is how to instantiate matured mobile technologies and form a business solution that is suitable for the organizational environment. The challenge leaves us with a research question for academia and industry: How can we engineer "mobility" in different business processes?

2.4.3 Requirements for a new approach

As we learned from the case studies, there are many good practices in the current approaches for BEaMS projects that should be kept and used. From these case studies we learnt that although many companies have an orientation towards business processes optimization, the adoption of mobile technologies frequently follows a technology-driven approach without precise knowledge of the potential benefits that may be realized (Kohler & Gruhn, 2004). There is a necessity to embed a "business engineering" perspective into the approach for adopting mobile technologies.

Business processes engineering is not straightforward, it is very complex; it involves more than just restructuring the workflow; it also involves changing the information flows around the business process and the knowledge management capabilities of the process Sawy (2001). A systematic procedure is required if a verifiable economic benefit is to be created by the use of mobile technologies especially in larger organizations with complex business processes (Kohler & Gruhn, 2004).

Therefore, we see the need for an approach that can be used to guide process engineering activities and there is a need for a support environment that facilitates this approach. The specific requirements for the new approach are listed below.

- Need for process modeling focus. There is a need to represent the mobile workflow in an organization using a specialized process model to identify potential process improvements. It should support analysis of the process model and identification of mobile business processes; redesign of the identified process; specification of the mobile element as required by the new processes; validation of the profitability of the change; and implementation of the change.
- Need for decision-making support. There is a need to support quick discovery of "as-is" model but this is not sufficient, because decision makers need to "rehearse" the future. So "what-if" model should be provided at the point of need. Using "what-if" model it should be possible to research integration of a mobile solution with existing business processes and to provide measurement functions in terms of efficiency, and productivity.
- Need to facilitate collaboration. As we have discussed in the conclusion, designing mobile workforce solutions is often conducted in a context of multi-actor systems. It is important to stimulate and support the participation of involved actors. A collaborative business engineering form of "thinking" is therefore needed rather than pure ICT system design "thinking".
- Need to cope with impacts. Organizations need to be notified of the impacts of mobile workforce solution on their organizational business environments. It is also important to help decision makers find creative ways of coping with changes caused by mobile workforce solutions.

Grounded on our view on simulation as a method of inquiry (see section 1.3), we propose to use simulation as a basis for the new solution, which aims to incorporate all these requirements. This will be further elaborated in the next chapter.

In a conclusion, the new approach needs to give directions as to how business processes maybe reengineered in the context of mobile workforce solution. It should present views based on existing research into Business Engineering best practices. The design method should work well with many actors and allow them to interact proactively with the potential organizational impacts. The design methods and the support environment must enable multiple partners to prototype and simulate new business processes.

Chapter 3 Principles of Business Engineering and Mobile Services

3.1 Introduction

Relevant concepts drawn from literature and from the exploratory case study are discussed in this chapter. We review the literature from three angles, i.e. mobile services in organizations, business engineering and decision enhancement services. In section 3.2, we discuss the categories of mobile services, the nature of mobile work, and organizational changes enabled by mobile services. We discuss in depth business process initiatives, business engineering approaches and business process simulation in section 3.3. In section 3.4, we talk about decision making and support, and decision enhancement services. An outline of the relations between the sections in this chapter is illustrated in figure 3.1. As shown in figure 3.1, we see mobile services in organization as an enabler of business engineering. Likewise, a business engineering approach is a way to achieve effective mobile services in organization. Both views are simultaneously necessary and important. Decision support may provide a solution to facilitate a balanced integral approach based on the two views.

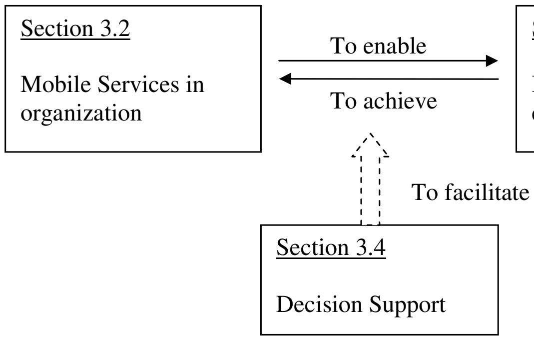

Figure 3.1 Structure of the chapter

3.2 Mobile services in organizations

3.2.1 Categories of mobile services

There are many ways to categorize mobile services (see definition in subsection 1.1.2). In viewing major technology enablers for mobile services, Jorstad et al. (2005) list the typical mobile services as follows:

- real time communication (voice, multimedia)
- browsing (WAP, HTTP, voice-enabled)
- messaging (SMS, MMS, e-mail, push-to-talk)
- presence-based services
- location-based services
- data synchronization (calendars, contacts, files)

- device management (remote configuration)
- data services (file transfer, e-mail download)
- gaming (download, interactive)
- streaming media (music, video, events)
- peer-to-peer communication (local, remote)
- m-commerce (micro-payments, finance)

Many researchers, with particular interests in business or management issues, suggest different categorizations of mobile services, which are mainly based on promising applications or user intention. Leem et al. (2004) summarize some of these categorizations on a timeline, see figure 3.2.

However, these categorization classification schemes are mainly based on the B2C perspective, i.e. mobile services for individual customers, and they do not differentiate between B2C and B2B/B2E services. With the fast growth of inter/intra enterprise mobile business, B2B/B2E oriented mobile services call for particular research interests. B2B oriented mobile services aim to improve the effectiveness and productivity of inter-business interaction between corporations, companies, business units, etc., and create new solutions for production processes with mobile technologies (Carlson, Walden, & Veijalainen, 2004). The same effectiveness and productivity-related value propositions can be applied to groups/teams and individuals, and mobile technologies can be realized by boosting distance working, simplifying administrative procedures and enhancing the effectiveness of team-work. This is how B2E oriented mobile services are defined by Carlson et al.(2004).

Category	Service
ARC Group (1999)	
Timeliness	E-mail/fax, stock information, news, sports information
Remote access	Intranet access, integrated messaging, banking/trading, reservation, e-commerce, sales support
Location based	Traffic information, weather information, vehicle location, navigation, entertainment
O'Loughlin (2000)	
Personal communication	Messaging, personal directory, community
Infotainment	Weather, news/sports information, catalog, mobile broadcasting
Mobile commerce	Ticketing, usage fee, coupon, banking/trading, auction
Business application	Conference support, intranet, e-mail, file transfer, DB
Remote control	Information appliance application, automobile application, navigation tracking, emergency service
Lehman Brothers (see Yoon et al., 2003)	
Communication	SMS (short messaging service), chatting, integrated messaging, e-mail
Information	News, city guide, directory service, traffic and weather
Transaction	Banking, brokerage, shopping, auction, reservation
Entertainment	Music, game, graphic, video

Figure 3.2 Mobile services classification schemes (Leem et al., 2004)

Leem et al. (2004) suggest a model to categorize B2B/B2E mobile services based on a value chain perspective - the scope of mobile services in a firm business process, see figure 3.3. In many cases, B2B/B2E mobile services are realized with mobile (enterprise) solutions providers rather than with internal development. Therefore, B2B/B2E mobile services are often called mobile solutions. In this research, we focus on B2E mobile services, which can be alternatively called mobile workforce solutions, because this is in line with our research scope directed by a meso-perspective on organization boundary, as presented in section 1.4. To enable easy understanding of our discussion, in the remainder of the thesis, the term mobile services (m-services) is generally used to refer to B2E mobile services and mobile workforce solutions.

Category	Description
Firm infrastructure	Not confined within in a specific primary activity, this BM is used in general decision making and information sharing
Procurement and inbound logistics	Mobile business or solution supporting firms' inbound logistics and aiming to work efficiently
Operation	Mobile business or solution used for firms' internal operation
Outbound logistics	Mobile business or solution supporting and dealing with outbound logistics
Marketing and sales	Mobile business or solution mainly used to support firms' marketing and sales activities
After service and system support	Mobile business or solution which facilitates and supports after sales and system support

Figure 3.3 Mobile B2B/B2E business model and description (Leem et al., 2004)

Since our focus in this research is B2E mobile services, we further describe a few interesting areas in which B2E mobile services can be expected to show benefits by the time this research is carried out.

Mobile sales-force automation
Sales representatives can efficiently access customer accounts through mobile devices and get up-to-date information, for example, on customers, products, stock levels, pricing and promotions before sales calls. Contracts and forms can be stored in the mobile device and quickly uploaded to a wireless network, reducing costs. Use of electronic signatures reduces the paper handling and increases the efficiency.

Mobile supply-chain management
Workers can gather information about products as they move through the supply chain, from raw material procurement to finished goods. Mobile services allow access to procurement portals to negotiate contracts for inventory or to partner extranets to react to customer demands faster. Mobile services can enable participation in online auctions and consideration of bids from multiple suppliers in real time, resulting in better pricing and lower transaction costs. Just-in-time supply chain information may improve visibility into the pipeline, which in turn may enable better decision-making.

Mobile access to email
Employees can stay in the loop with management, co-workers and customers when they are away from their desktops. Mobile access to email keeps them connected and enables them to act quickly on new developments triggered by email alerts. Timely access to key information allows employees to make better decisions and react quicker to customer needs.

Personal Information Management (PIM) applications
Employee productivity can be enhanced by providing anytime, anywhere access to applications on the corporate networks, such as contract lists and calendar information. Extension of corporate intranets to mobile devices is being adopted quickly because it gives employees real-time access to documents, discussions and centralized information. Organizations can realize significant savings

by reducing expenditures on manuals and memos and eliminating the cost of distributing and storing standard documents and forms.

Mobile tracing and tracking
Location based services through wireless and GPS networks to track the geographic location of workers or workspace. The positioning information can also be used to optimize transport routes and lead times. Positioning is also beneficial for the security of individual independent workers.

Mobile dispatching and scheduling
Dispatch of work orders can be distributed by the work planner or received on request from the field worker real time. Work orders can be accepted, rejected and their status (e.g. interrupted) including cause can be monitored. It can also bring the possibility to send work order reports to the office for inspection and invoice handling. Optimization algorithms can be used for decision support of scheduling and rescheduling, allocation of resources, and minimization of transport in real time. Statistics is an important tool in analyses of lead times and utilization of resources.

3.2.2 The nature of mobile work and mobile services

Existing information systems research has mainly been focused on the stationary office environment. However, recent developments in wireless telecommunications and mobile computing require us to rethink many fundamental assumptions underlying IS research (Lyytinen & Yoo, 2002). In order to make a clear and comprehensive understanding of mobile work and supporting mobile services, we need to answer the following fundamental questions: Who are the mobile workers? What is the nature of the tasks performed by mobile workers? What are the characteristics of the mobile environment or context?

Yuan and Zheng (2005) conducted a study on the nature of mobile work support, looking at four fundamental aspects: mobile workers, mobile tasks, mobile context, and mobile technology. Adapting from their work, we define the following framework (see figure 3.4) to guide our discussion in this section. Following the framework, we view mobile service as a central link of the four aspects: mobile services are enabled by mobile technologies, and designed for mobile workers to accomplish mobile tasks within certain mobile contexts.

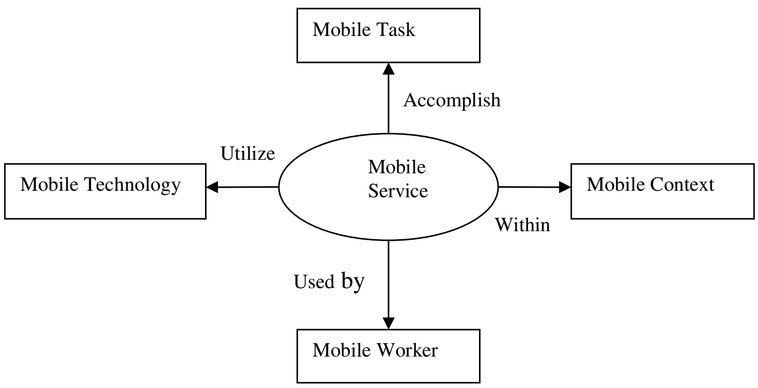

Figure 3.4 Understanding the nature of mobile services (adaptation from Yuan (2005))

Mobile worker

The term mobile worker is used to describe a person who is in some way physically mobile in their work. In general, a mobile worker can be defined as a worker who is away from the office or desk for more than 20 percent of the time, who has a job with no desks or office, or who must perform work that requires mobile communications (Gartner, 2002). Other terms also have been coined to describe the mobile worker, such as "road warriors" and "nomads". These terms distinguish workers who are moving, from workers who are distributed and co-located (Dahlbom & Ljungberg, 1998).

Mobile workers can be further classified based on the concept of mobility. There are two kinds of mobility (Bellotti & Bly, 1996; Kristoffersen & Ljungberg, 2000; Whittaker, Frohlich, & Daly - Jones, 1994; Yuan & Zheng, 2005). One is local mobility, also called wandering, which refers to people spending a considerable amount of time walking around locally. The other is remote mobility, which includes traveling and visiting. Traveling is the process of going from one place to another in a vehicle. Visiting is spending time in one place for a prolonged period of time before moving to another place.

It is stressed by Brodie and Perry (2001) that mobile workers include not only knowledge workers, so called white collar workers, such as managers and real estate agents, but also field workers, so called blue collar workers, such as taxi drivers and field workers. The leading job categories of mobile workforce include general executives, sales, transportation, construction, field service, healthcare, finance and education. These workers make up 78 percent of the total mobile workforce (Gartner, 2002).

Knowing who mobile worker are helps us to identify the right target for mobile services. It is also important to consider the characteristics of various mobile workers in order to tailor mobile services to meet their specific needs. For example, a field service engineer may require a more user friendly and robust mobile device than a business consultant.

Mobile task

Mobile tasks require mobile workers to be present on the site physically and usually need to be finished within a specific time period, such as for service delivery. So, location/time dependency is a very important characteristic of mobile tasks (Balasubramanian, Peterson, & Jarvenpaa, 2002). Wiberg and Ljungberg (2000) examined how the work of mobile telecommunication engineers in Sweden is dependent on place and time. Mobile workers often have places of non-negotiable importance, that is, travel could not easily be avoided: you cannot reframe the earth by reducing distance. Because of place dependence, there are time frames that seem very difficult for mobile workers who have to do certain tasks within a certain time. Mobile work has time frames that are not negotiable, so the work is dependent upon them.

Another feature of mobile tasks is associated with multi-task handling, such as talking on a mobile phone while driving (Yuan & Zheng, 2005). As a consequence, mobile work may experience attention distraction problems while conducting mobile tasks. Kristoffersen and Ljungberg (2000) also confirmed that mobile workers often have to use their hands to manipulate physical objects, as opposed to workers in the office setting, whose hands are safely and ergonomically placed on a keyboard. Mobile workers may be involved in tasks that demand a high level of visual attention, to avoid danger as well as monitor progress, as opposed to the traditional office setting where the greatest degree of visual attention is usually directed at the computer monitor.

Moreover, there is less predictability with mobile task (Perry, O'hara, Sellen, Brown, & Harper, 2001). That is, there are more uncertainties or exceptions in mobile tasks. For example, while performing planned tasks, mobile workers may encounter unplanned situations. This feature will be further elaborated when we later discuss the characteristics of a mobile context.

Mobile context

We define the mobile context, or the context of mobile work, as the circumstances in which mobile tasks are carried out by mobile workers. Place and time are very important for understanding a mobile context (Wiberg & Ljungberg, 2000).

The constraints of place have a great impact on the kind of work activities that can be carried out. For example, place may be an important determinant in the ordering of work tasks for mobile workers. If a task must be carried out, resource limitations often constrain the methods available to perform the task (Gray & Salber, 2001). For example, mobile work facilities are often limited due to the inadequate capability of mobile devices and communication channels or environmental constraints.

Hence mobile workers need to adapt to the different and diversified workplaces. These different places facilitate or restrict the workers with different possibilities for configuring and reconfiguring their relationships with others, different possibilities for performing actions, different possibilities for habitual action through which meaning and identity could be attached to place, and different possibilities for temporal structure configuration (Brown & O'hara, 2003).

Yuan and Zheng (2005) compared the temporal structure of the mobile context and stationary context, and found that: the temporal structure of mobile work is more irregular; the time frame is narrower, which means more urgent and time critical in information access and exchange in the context of mobile work; and time management is less controllable, which means in some time frames, a mobile worker does not have the available resources to perform the task he/she wants to do, thus there exists “dead time”, i.e. time that occurs between tasks, in which the workers usually have little control over the resources available to them (Perry et al., 2001).

The physical environment of mobile context may be also very different from that of stationary context. In the case of Railpocket Connection (chapter 2), we see the mobile services rely on fast interactions in sometimes noisy and deskless environments, rather than on quiet and stable office-usage.

Given location sensitiveness in the mobile context, many mobile services also explore properties of context as part of their functionality, that is, context-aware mobile services. For instance, a mobile service might make use of the position the user is at, the presence of other users nearby connected in ad-hoc networks, or information provided by objects, using e.g. RFID-tags.

Mobile technology

Mobile devices and wireless network infrastructure are the two most important technology components to enable and host mobile services. Thus, we discuss mobile technology in terms of mobile device and wireless network infrastructure.

The most unique and distinguishing characteristic of a mobile device is its portability. Portability sets requirements for appropriate size and weight, thus sets constraints on interface, input, memory, power etc. too. Kristoffersen and Ljungberg (2000) distinguish between four major categories of mobile devices to describe what they perceive to be key types of mobile technology in respect to their purpose and their characteristics: the mobile phone, the PDA, the hybrid, and the mobile information appliance.

With the continuing development of mobile technology, we see the above categories have become unsuitable due to the variety of mobile devices on today's market. Mobile phones are rapidly merging with other previously distinct products such as PDAs, tablet PCs, cameras, MP3 players, and radios. For example many smart phones are equipped with basic PDA functions and data transfer functions, in addition to voice communication. We follow Nielsen (2001), and think it is more meaningful to distinguish between task-specific and general-purpose mobile devices; both in relation to PDA's and to cover the 'hybrids' presented in (Kristoffersen & Ljungberg, 2000) and thus get the following classification.

- General purpose device: these cover general communication devices which aim to be a mobile communication central, allowing the user to e.g. access web pages and write email in addition to using the ordinary phone connection. A Blackberry PDA is an example of general purpose mobile device, see picture below.
- Task-specific devices: these can be seen as task-specific computational devices, which aim to support the user to accomplish a set of specific tasks. An example of such task-specific device is a Symbol handheld with embedded bar code scanner, see picture below.

Figure 3.5 Examples of general mobile devices and task-specific mobile devices: Blackberry PDA (left) and Symbol handheld (right)

A broad range of communication technology is available for the network technologies: operator-driven networks, e.g. GSM, GPRS, UMTS, and self-organized networks, e.g. WLAN, Bluetooth, ad hoc. In other areas of wireless technology, developments are moving rapidly. For example, the satellite Global Positioning System (GPS) allows an increasing level of accuracy for the locating of people, and is broadly available for navigation and other location based services. Radio Frequency IDentification (RFID) is another example of a fast growing mobile technology, which is mainly used in retail and logistics, for tracking and tracing within the supply chain, and for improving customer profiling.

Given the scope and the focus of this thesis, we will not expand our discussion on the technology terms. Also we point out that we cannot have a comprehensive discussion on mobile technology, given the fast pace of developments in this domain. Current explanations of mobile technologies can be found in (Koivukoski & Raisanen, 2005; Rackley, 2007; Shorey, Ananda, Chan, & Ooi, 2006).

To sum up, fast growing mobile technologies enables the development of various mobile services, targeted at mobile workers. Mobile services support mobile workers and help them to accomplish their tasks in a mobile context. As we have discussed, the introduction of mobile services into the work context may affect the spatial and temporal dimensions of mobile workers' tasks and hence the whole work processes. Thus it is crucial to expand our perspective on process changes enabled by mobile services.

3.2.3 Process changes enabled by M-Services

The main characteristic of m-services is their ability to provide coordination, control and decision support within the business process under the restriction of spatial limitations (Valiente & van der Heijden, 2002). Consequently, m-services can enable changes in business processes which have a distribution structure and where the process-executing persons have certain mobility. Kohler and Gruhn (2004) discuss the characteristics of such business processes and use the term "mobile business processes" to refer to them. They define a "mobile business process" by looking at its decomposed process partitions (sub processes) and obtain the following aspects:

- "Uncertainty of location": the place of the execution of an activity can be different in different instances of the business processor, and the places can change during the execution of an activity (Valiente & van der Heijden, 2002).
- This "uncertainty of location" is caused by external factors and the process-executing person therefore has no freedom of choice regarding where the process execution takes place.
- Cooperation with external resources is needed in the execution of the process, for instance communication or coordination with other persons or interaction with other objects.

Kohler and Gruhn (2004) use the following example to illustrate their definition of a mobile business process: at the moment of the customer inquiry the place where the field staff will meet a customer for a sales conversation is unknown (location uncertainty). During the sales conversation the field staff interacts with the customer and possibly simultaneously with the information system of the company (cooperation with external resources). Thus, (mobile worker) serving an inquiry at a customer site is a "mobile business process". In contrast, an employee working on office duty, and moving his wireless LAN-connected notebook to the conference room for a short time, does not conduct a mobile business process because there is no compulsory location uncertainty, i.e. his movement is not externally triggered.

The term "process changes" is used collectively to refer to the multiplicity of theoretical or practical approaches that have been proposed in recent years to assist organizations to plan, manage, and co-ordinate their change initiatives (Giaglis, Hlupic, Vreede, & Verbraeck, 2005). To facilitate an understanding of process changes enabled by m-services, it is worthwhile to consider the Freedom Economy concept to explain the future of mobile business (Keen & Mackintosh, 2001). According to Keen and Mackintosh, the value of mobile technology in business processes lies not in their convenience, simplicity or immediacy within existing routines but in the freedom it creates by following one major rule.

Valiente and van de Heijden (2002) proposed a method to derive organizational changes enabled by m-services by taking the existing business process and by gradually increasing the mobility of the participants in the process, and complicating their locations by different degrees of uncertainty. Indeed it appears to be quite obvious that the more mobile the actors are or the higher their location uncertainty is, the less feasible the use of traditional information systems becomes for coordination and decision making.

Motivated by the work of Keen and Mackintosh (2001) and Valiente and van de Heijden (2002), Kadyte (2005) adopts a process approach to utilize mobile services in customer care operations, specifically focusing on cross-boundary process improvement. His major finding is that mobile service by itself can not contribute to performance; people, systems, and processes must work in concert to achieve higher performance. In the next section, we will look more broadly at the current design approaches of m-services in organizations.

3.2.4 Design approaches for mobile services in organizations

The approaches and technologies for designing mobile services to support new ways of working are still the subject of research. Nevertheless, they are likely to "borrow" concepts and technologies from a variety of fields, such as workflow systems, CSCW, software engineering, mobile computing and so on. Ljungberg et al. (1998) summarized four perspectives of mobile service design research, as shown in figure 3.6.

Competence area	Interest	Approach	Perspective		Objective
Users	guide the design of future IT use, i.e., future work or leissure activites.	involvement in R&D (participatory design)	"use domain" experience	→	The design of useful IT artifacts to be incorporated in work or leissure activites, i.e., IT use.
Social scientists	understand practice (interpretation)	qualitative research (description)	Practice	→	Collect a rich body of empirical research on the role of mobility in work (and life in general).
Informaticans	innovation of new IT use - idea geneation - evaluation	idea generation and evaluation of new IT use based on empirical experiences and technological potential	IT use	→	Suggest new ways of IT use in mobile situations by exploiting the potential of technology and conduct empirical research (here: innovation on mobile informatics)
Computing scientists	engineer artifacts	construction	IT	→	Construct and implement new applications.

Figure 3.6 Four perspectives of mobile service design research (Ljungberg et al., 1998)

Being aware of the existence of different research perspectives, we carried out a literature review on mobile service design approaches from different disciplines.

We found that most design approaches for engineering mobility are targeted at issues at the individual level. For example, Sawyer and Tapia (2003) view mobile work from the task redesign tradition. Work redesign provides a means to link work to a larger context including the use of various technologies. They propose a (work redesign) framework to explore and understand organizational governance of mobile work by focusing on four elements: design of the work tasks, including allocation of subtasks, coordination needs, and oversight requirements; determining group norms of process and performance; composition of the group, including both people and tools to support people's work; and governance structures and requirements.

The work of Dyson and Er (2004) is an example of design approaches focusing on individual acceptance issues. They propose a hybrid design approach to the development of mobile systems in the construction field. This approach is designed to overcome challenges like resistance to information technology by construction workers, reluctance by management to spend money on untried technologies and on training, and practical difficulties which effectively limit user participation in the design process.

There are a few research attempts with a clear "process" perspective. For instance, Sorensen et. al (2002) suggest different attributes that can be used to describe mobile work processes. They present a characterization framework focusing on the mobile work and try to derive the functionality, architecture and hardware required to support specific mobile scenarios. They hold the perspective that "in a real mobile work situation there are more factors than mobile technology to consider, such as co-operative work and time and location constraints of the tasks themselves." They believe that using such a framework help explore typical classes of mobile work with different process and transaction support.

The work of Pulli and Antoniac (2002) is another example of a "process" centric design approach. They present a scenario-based analysis and design approach for mobile and ubiquitous service development. They propose early visibility of services through partial service scenarios and the use of different levels of abstraction and detail during lifecycle of development to narrow-down design choices and still allow creativity and innovation, i.e. to try to encourage diversification through experimentation, and to evaluate and constrain the best variations for further development through a value function framework.

We found that no design approach has been reported with a focus on issues related to mobile workforce solutions at the organizational level. Probably it is too early for this to be an issue now and we will see this in management literature when the changes at the process and the individual level have become more crystallized.

The literature review showed that a number of services to support business process have been developed to address the needs of workers whose work situation is inherently mobile. Designing such mobile services involves complex activities and involves many actors i.e. problem owners and stakeholders, who have different goal and objectives in the design process. We look at designing mobile services for supporting new ways of working as a problem solving process due to the fact that several possible courses of action can be identified to improve the problem situation, and that the new mobile workforce environment contains factors that affect the possible courses of action that designers can take. Though different design approaches have been proposed or practiced, none of these approaches are rooted in a problem solving thinking. To form a problem solving based design approach, it is worthwhile to adopt a business engineering perspective.

3.3 Business engineering in general

As presented in subsection 2.4.3, we learnt, through the case studies that there is a need to study how business processes maybe reengineered in the context of mobile services in organizations. In this section , we take a look at business engineering in general to get an in-depth understanding of this subject.

3.3.1 Business process initiatives

In this section, we discuss the role of business processes in organizations' management agenda to date, based on our understanding on the evolution of business process initiatives, from workflow management to business process management (BPM).

Business processes are increasingly recognized as the key to competitive survival. Contemporary change management approaches advocate that businesses should not be analyzed in terms of the functions into which they can be decomposed or in terms of the products they produce, but in terms of the key business processes that they perform (Giaglis et al., 2005).

The term "business process" is an important concept and has received much attention and many interpretations from different perspectives. A number of specific definitions have become widely adopted in the literature on the design and management of business processes (Adesola & Baines, 2005). Some common elements can be identified in a majority of definitions. These elements relate to the process, usually described as transformation of input, workflow, or a set of activities; process input; and process output usually related to creating value for a customer, or achieving a specific goal (Paul, Giaglis, & Hlupic, 1999)

A *business process* is an ordered execution of activities by people playing organizational roles in order to produce goods or provide services that have add value in the organization's environment or to the organization itself (Eriksson & Penker, 2000). Each activity on its own can be regarded as a decomposable process, and as a sub-process of the containing process. For example, a sales process may contain a delivery activity that contains nested activities for the selection of a transport provider and the transport.

Business process initiative forms the underlying importance of the way that corporate work is organized as overall business processes for the profitability, effectiveness, and efficiency of organizations. Once an organization perceives its business in terms of business processes there is usually considerable scope within which these processes may be redesigned to yield drastic improvements (Valiris & Glykas, 2004). Given the importance of business process initiatives, different approaches have been studied to engineer business processes in the past decades.

3.3.2 Business engineering approaches

Hammer (1990) and Davenport and Short (1990) were the first to report on more or less systematic approaches that can be used to produce radical performance improvement of entire business processes. Their major vehicles are the application of information technology and the promotion of changing the structure of the process (Reijers, 2002). This approach was coined with the terms "Business Process Reengineering" by Hammer (1990) and "Business Process Redesign" by Davenport and Short (1990). There are many terminologies that are loosely associated with the approach, e.g., Business Process Improvement (Harrington, 1991), Business Process Transformation (Burke & Peppard, 1993), and Business Process Management (Galliers, 1991). Despite the variations, the concepts behind these approaches are essentially so similar that it has led practitioners to substitute one term for the other effortlessly (Reijers, 2002). In this research, we follow Meel and Sol (1996) and refer to the general concept as "Business Engineering".

A plethora of BE methodologies have been identified in the literature. These can be classified into three main categories depending on the perspective they take in BE (Greasley, 2003): management accounting, information system (IS) development and organizational theoretic categories.

- Management accounting BE methodologies view the organization from a process perspective. In the management accounting perspective, analysts attempt to reorganize business processes and use IT as an enabler in their effort. Accounting methodologies concentrate more on business analysis rather than business modeling which is performed using very simplistic modeling techniques such as process diagrams and flowcharts.
- The organizational theoretic perspective concentrates more on understanding and analysis of an organization based on principles like accountability and the methodologies add more elements to business modeling and analysis by addressing the need to focus on people (agents), their accountabilities, roles, interactions, activities and use of available resources.

- IS methodologies usually add one more perspective to the process perspective of the accounting BE methodologies. This is the structural (or data) perspective where static business elements are identified. IS methodologies are based on IS design, with the argument that the design of IS should be aligned with the design of the corresponding organizational processes because IS in an organizational context are used to support some kind of business activity (Paul et al., 1999).

Analysis and redesign of business processes are the focus of many BE approaches. The common central questions to be answered by BE projects are, for example, how to design or redesign an effective and efficient business process in practice, how to determine the performance of a business process, or how to allocate resources in an operational business process.

Kettinger et al. (1998) conducted an empirical review of existing methodologies, tools and techniques for business process change, and point to the lack of a comprehensive, scientifically grounded design methodology to structure, guide, and improve organizational design efforts. Kettinger et al. (1998) argue that there is a need for more user-friendly and 'mediarich' capture of business processes, and that simulation can accommodate these requirements by providing easy visualization and allowing team participation in process redesign.

Meel and Sol (1996) provide a thorough introduction to the use of simulation for the integrated modeling and analysis of business process and information systems. They advocate the development of computer-based dynamic models of business processes as a crucial mechanism to support the process of business engineering. Hansen (1994) also advocates the appropriateness of simulation for Business Engineering, arguing that "an engineering approach to process reengineering that incorporates modeling and simulation is necessary".

As process changes happen over time, simulation appears to be a suitable process modeling method. The interaction of people with processes and technology results in an infinite number of possible scenarios and outcomes that are not possible to predict and evaluate using widely popular static process modeling methods (Hlupic & Robinson, 1998) .

3.3.3 Business process simulation

As we have discussed, business process modeling is central to business engineering. A majority of software tools for business process modeling have an origin in a variety of process mapping tools that provide the user with a static view of the processes being studied (Hlupic & Robinson, 1998). Most of these tools only provide a basic calculation of process times or allow some attributers to be assigned to activities to enable some sort of process analysis, but are not able to model the dynamics of business processes and evaluate the effects of stochastic events and random behavior of resources.

As a solution, simulation models, i.e. discrete-event simulation models, can provide organizations with dynamic insights into business processes, and has become a powerful methodology for business process modeling (Bhaskar et al., 1994; Swami, 1995; Tumay, 1996). Business process simulation supports performance analysis and design of future processes.

Simulation fundamentally enhances process performance analysis by introducing dynamic parameters of the process, like times, volumes, capacities and quality (Greasley, 2003). It can predict process performance along a number of measures such as lead-time, resource utilization and cost. It provides a much better picture of bottlenecks, hand-over times and dynamic performance than a static analysis.

Business process simulation research is built on the field of simulation in general. The concepts underlying simulation include system and model, events, entities and attributes, activates and delays etc. Detailed information on these topics is available from (Banks, Carson, Nelson, & Nicol, 2000; Law & Kelton, 2000).

Many researchers in the simulation field proposed a set of high level steps to guide a simulation study (Banks, 1998b; Cohen, March, & Olsen, 1972). The most common steps are: conceptualization, specification, verification & validation, and experimentation & solution finding.

- Conceptualization: the abstraction of a real-world system under investigation by a model, a series of mathematical and logical relationships concerning the components and the structure of the system (Banks, 1998a).
- Specification: the collection of empirical data and the specification of attribute values of the objects specified in the conceptual model in a computer-recognizable simulation model.
- Verification and validation: the process of determining the simulation model is coded correctly and represents adequately the problem considered.
- Experimentation & solution finding: the process of designing appropriate scenarios and carrying out experiments to identify problems and solutions to the problems.

To sum up, the business engineering perspective, built upon problem-solving thinking, can be viewed as a starting point towards a systematic design approach for mobile services in organizations. Particularly, business process simulation might provide a solution to gain insights into the dynamic aspects of organizational (process) changes enabled by mobile services, for example, the spatial and temporal changes of a mobile context and the related changes of the entire business process. Nevertheless, we still do not have a comprehensive view of how to construct the desired approach for business engineering enabled by mobile services. The concept of decision enhancement services may help us gain a better view of that.

3.4 Decision Support

As we have learned from the case studies in Chapter two, designing mobile solutions for business customers is a complex undertaking because it requires at least two organizations, including their multiple actors, to balance different working needs. On the one hand, the inadequate knowledge of managers who do not have a clear idea of how to use the opportunities presented by mobile technology is one major factor inhibiting mobile business (Lehmann, Kuhn, & Lehner, 2004). One the other hand, many predictions about the impact of mobile commerce in business are over-hyped by consulting bodies and many companies are holding back on investing in mobile technology until it is stable and the benefits are obvious (Kadyte, 2005). The challenge becomes clear: What are the core issues involved in developing value-added mobile services in the business domain? Decision support and tools are important for taking this challenge.

3.4.1 Decision making and decision support

Organizations are defined as purposeful systems (Ackoff & Emery, 1972; Sol, 1982). An organization can be seen as a dynamic collection of choices looking for problems, issues and feelings looking decision situations in which they might be aired, solutions looking for issues to which they might be the answer and decision makers looking for work (Cohen et al., 1972).

A decision is an outcome of the interplay between problems, solutions participants and choices, all of which arrive independently and change continuously. Simon (1960) describes three stages in the overall process of decision making.

- Intelligence, finding occasions calling for a decision
- Design, inventing, developing and analyzing possible courses of action
- Choice, selecting a particular course of action from those available

Simon (1960) distinguishes between a rational and behavioral model of decision making. He introduces the concept of bounded rationality to deal with the imperfection of human decision making. Bounded rationality refers to the fact that decision-makers are not perfectly informed and do not have unbounded information processing capabilities. Sol (1982) argues that a simulation based inquiry system guided by the paradigm of bounded rationality, presents instruments for:

- the creation of evidence in a data-void environment, by generating data not previously available, or by generating data that reflect different alternatives to reach a decision
- the generation of action alternatives in relation to the existing situation as a frame of reference

Organizational decision making typically requires communication and coordination among the organizational units involved in the decision making process. So, decision support is not just about software, models and tools: decision support is about making decisions following a method of inquiry. According to Sol (1982), simulation is an effective method of inquiry for organizational decision making. Sol states a simulation inquiry system is able to address the following organizational decision making requirements:

- the possibility to emphasize the activity of conceptualization by presenting freedom for the construction of a "base model"
- the possibility to construct a model system in view of the availability and attainability of data, and to place it in an experimental frame
- the possibility to generate alternative solutions and analyze these in comparison with the initial specification

3.4.2 Decision enhancement services

A new paradigm in decision support is the Decision Enhancement Services (DES) presented by Keen and Sol (2007). In this paradigm, the concept of "studio" is introduced, and this refers to a facilitative environment where decision enhancement is processed and achieved. The goal of a studio is to help managers rehears the future by building their comfort with, and confidence, in directly using appropriate simulation models, information systems, analytic methods and interactive tools in their own decision processes.

According to (Keen & Sol, 2007), decision enhancement comprises three elements: the target (decisions that matter), the process (studios), and the technology (suites).

- *Decisions that matter* are the ones where complexity, uncertainty, the importance and reliance on human judgment and interaction, and the need to include many parties with often differing perspectives and priorities have in general limited the direct use of information technology models and analytic aids.
- *Studios* are facilitative environments, face-to-face links or via telecommunication links that enhance active inclusion in the process of stakeholders and build the collaboration that is an intrinsic requirement for effective processes to handle decisions that matter. A studio has technology suites.
- *Suites* are integrated IT development tools, systems and analytic methods that focus explicitly on enhancing the studio decision process. They rely on visual representations of the decision context and displays of outputs from the models, as well as numbers and text, to best mesh how the people involved think and communicate with how the suites respond.

Studios and suites targeted on decisions that matter comprise services to the people who make the decisions, not a technical product. The following actors can be distinguished in general in a decision enhancement services (Keen & Sol, 2007)

- Stakeholders: these actors make the decision and are committed to the results. Since stakeholders are most often senior members of an organizations, they commonly don not create the models themselves and are merely interested in the output of a rational inquiry, both substantive and procedural.
- Non-stakeholders: these actors are involved in the process of decision making, but have no stake in its outcome. Consultants, supporting staff, system administrators and the actual model builders are often non-stakeholders.

By emphasizing the studio (process), and the suite (system-based tool), DES offers practical ways for technical professionals to move their services from useful to usable to used, instead of being far too often stuck in proposed designs (i.e. usefulness), pilots and prototypes (i.e. evidence of usability) and limited adoption and diffusion (i.e. usage)". Keen and Sol (2007) further argue that effective decision support should be based on three U's.

- Usefulness: relates to analytical methods, information resources, and embedded knowledge. It represents how appropriate the methods and resources are applied to support decisions.
- Usability: is the mesh between people and technology, its responsiveness and adaptability, and the ease of interaction and collaboration it enables. It is the interface between the user and the suite of the decision support technology.
- Usage: it depends on the embedding of the decision support studio and its suites of tools in the decision process itself.

In our case, "decisions that matter" is the effort of "business engineering and mobile services". A targeted studio with appropriate suites remains to be developed. We notice that building the powerful technology suites is important but this should not be the only focus; it is more important to embed suites in the processes and interactions to form a studio, in which users work together to make choices and commitments.

A decision enhancement process with a support studio follows the steps shown in figure 3.4, which will be further discussed in chapter four.

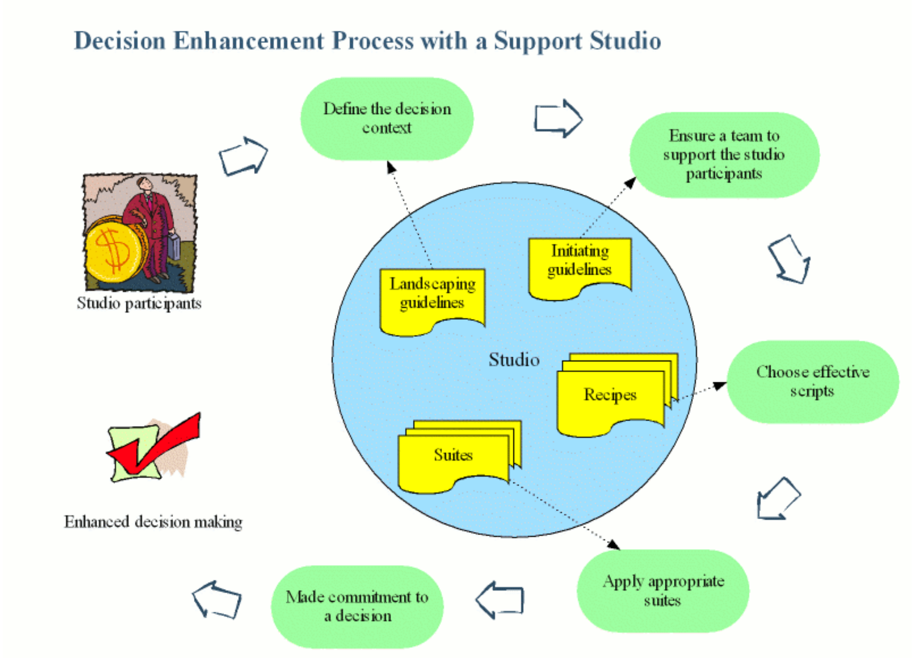

Figure 3.4 Decision enhancement process with a support studio

3.5 Reflection

The purpose of this chapter was to present and discuss the relevant principles of business engineering and mobile services from literature. In chapter one, we briefly discussed and defined business engineering and mobile services (BEaMS). In chapter two, we carried out case studies that enabled us to understand the real issues in the practice of BEaMS projects, with a focus on eliciting requirements for improving the effectiveness of the design approach for BEaMS projects. In this chapter, we provided a sound theoretical background on the domain of BEaMS to help us define the relevant concepts for our support studio.

Though we have defined m-services in chapter one, we can enhance our understanding on the concept after exploring the nature of mobile work and mobile services in section 3.2. The definition of *mobile service* is refined as follows: a mobile service is based on a mobile network and consists of user-specific applications that enable access to the content on/through a mobile device. The added-value of a mobile service for a mobile worker lies in its support for accomplishing a mobile task in a mobile context.

A business engineering approach with an emphasis on process modeling and simulation is an important initiative towards designing value-added mobile services in organizations (section 3.3). This initiative is in line with our research objective to improve the effectiveness of BEaMS. To facilitate the actual steps leading to achieve the objective, the theory of decision enhancement services is introduced in section 3.4. The studio concept defined in this chapter, and its underlying way of thinking, is used as a basis for developing the support environment in chapter four.

Chapter 4 A Studio based Approach for BEaMS

A key factor towards an effective approach for business engineering and mobile services (BEaMS) is to develop a support studio, based on the important principles we discussed in chapter three. In this chapter, we start by outlining the requirements for, and constructs of, the studio in section 4.1. Successively, the content of the studio is further specified in sections 4.2, 4.3, 4.4 and 4.5. Conclusions are drawn in section 4.6.

4.1 Requirements and constructs

4.1.1 Requirements for the support studio

Developing a mobile workforce solution is a complex task, especially when one considers its implementation. At present, mobile workforce solutions basically support the automation of existing and traditional business processes, for instance, the transition from paper-based processes. There is surely a potential for organizations to engineer "mobility" further; and we argue that to support this effort, more value lies in process alignment. The creation of business processes alignment calls for an appropriate engineering approach. Industry requires such approaches and support tools as revealed by the case studies.

Through the case studies presented in Chapter 2, we found out that the current effectiveness of BEaMS projects can be improved further, to support the analysis and identification of mobility issues in business processes. Grounded on those findings (also see chapter 2, sub section 2.4.3), we summarize general requirements for our support studio for BEaMS regarding the following aspects.

Increasing process-awareness: there is a need to increase process-awareness in the engineering approach and a need to take into account the potential impact of the mobile workforce solution on organization, processes and individuals. It leads to the following requirements for the support studio.

Requirement 1: The studio should provide guidelines that enable stakeholders to increase the awareness of the potential impacts of mobile workforce solutions on organizations, business processes, and individuals, and trigger a proactive approach for BEaMS.

Communication between stakeholder perspectives in the team: there is a need to facilitate communication between process designers, service developers, project managers and end users in the engineering approach. It should facilitate the service developers to handle the various points of view of the stakeholders. This leads to the following requirement for the support studio.

Requirement 2: The studio should facilitate effective means of communication between stakeholders, e.g. process/service designers, management and the mobile workers.

Focused design process: given the novelty and complexity of mobile technology and its business applications, it is vital that the design process of mobile services remains focused. The stakeholders should be able to focus on the important mobile workforce service design issues, and not be distracted with too much detail that diverts their attention from the key aspects of designing solutions. This leads to the following requirement for the support studio.

Requirement 3: The studio should enable process/service designers to focus on the relevant design issues and guide their efforts on context specific issues.

Modeling support: there is a need for effective capture of an "as is" model of targeted business processes and a need for decision-making support on "what-if" analysis, which allows us to conceive potential new service, research the integration of the service with existing business processes and to provide a measurement function in terms of efficiency and productivity. This leads to the following requirement for the support studio.

Requirement 4: The studio should support service designers addressing the creative process of conceiving potential services by providing dynamic models of the targeted business processes.

4.1.2 Construct of the support studio

The steps of a decision enhancement process with a support studio based on the work of Keen and Sol (2007) is demonstrated by figure 3.7 in chapter 3. As can be seen from the diagram, a support studio consists of elements such as landscaping guidelines, initiation guidelines, recipes and suites. The number of these elements is not fixed, but the studio should have at least one of each for the purpose of enhancing a decision process.

The guidelines for landscaping and initiating are generic, and the recipes are more specific. For "landscaping", we define guidelines for engineering mobility in organizations at a strategic level. For "initiating", we provide tactical guidelines to set up a team to control engineering activities. We reflect these guidelines in a number of operational scripts for BEaMS practice and present that as recipes. We develop a set of domain-specific simulation building blocks for modeling the relevant business processes, which forms a suite. The purpose of this suite is to support the implementation of part of the recipes that we proposed. An overview of the studio constructs is given in figure 4.1.

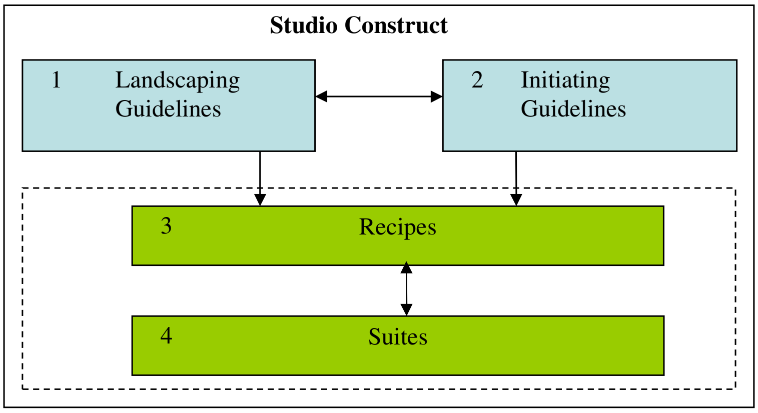

Figure 4.1 Studio construct in general

The construct of the support studio presented in this section is aligned with our point of departure on simulation as a method of inquiry; see chapter 1, section 1.3. We claim that such a construct ensures a simulation based studio, not only because it contains a simulation suite as a key element, but also because it reflects the simulation based inquiry methodology, as defined by Sol (1990) using the "four ways" framework: way of thinking, way of controlling, way of working and way of modeling. Such a construct implies a framework for studio based BEaMS approach.

- *Landscaping guidelines* concern how to form a starting point (or "awareness") among stakeholders, and it reinforces a way of thinking
- *Initiating guidelines* concern how to set up a project team and build consensus, and it reinforces a way of controlling
- *Recipes* describe a set of steps of how to ensure a process- driven approach, and it reinforces a way of working
- *Suites* consist of a domain specific simulation library, and it reinforces a way of modeling

Next, we discuss how the fulfillment of the studio is carried out, towards a studio-based approach for BEaMS.

4.2 Landscaping Guidelines

Landscaping is about forming a starting point among decision makers, explaining what and why of mobile services, and reinforcing a way of thinking. In this section, we provide guidelines for BEaMS projects at a strategic level, and expect that awareness can be shared among decision makers throughout their use of them. The guidelines are derived from an analysis of the case study through which we learnt that it is important to understand the way that mobile workforce solutions create business value, coupled with the need to understand the different types of mobile computing and mobile infrastructure available today. These two issues are considered to be of paramount importance in a BEaMS project. The guidelines are discussed and explained as follows.

4.2.1 Form a systems view: balance between hard and soft system thinking

The aim of this guideline is to form a systems view on BEaMS projects. An organizational definition of *system* is a complex grouping of human beings and machines for which there is an overall objective (Checkland, 1981). Optner (1965) gives four reasons for using the "systems" concept: firstly, many problems are seen to recur when they are looked at as problems of systems; secondly, the systems view enables problem-solving to concentrate on the processes by which things are done, rather than on (ad hoc) "final outcomes"; thirdly, systems many provide the objective standard by which problems can be organized for solution; from objective standards we may be able to gain greater insight to generalize on business phenomena; fourthly, since many business problems have both qualitative and quantitative attributes, systems analysis seems to be the method most likely to be brought to these mixed problems.

According to Checkland (1999), systems must be developed for the organization as a whole rather than for functions in isolation. If this principle is not followed then a small part of the organization may not be operating to the benefit of the organization as a whole. This also places emphasis on the importance of recognizing that organizations are open systems that interact with their environment. We adapt this view from Checkland (1999) and argue that the design of mobile workforce solutions should not be done in isolation of the rest of the organization. In principle, hard systems thinking and soft systems thinking should be applied to look at an organization before the introduction of a mobile workforce solution. Systems views can be used in tackling ill-structured problems such as designing mobile workforce solutions.

Optner (1965) states that a problem-solving methodology for business and industry should examine business problem solving from all sides, angles, and level, and to do so via the concept of business as a system. This enables us to extract both the general and special properties of a problem, thereby persuading business executives not to treat solutions to problems as special cases but to look upon their normal professional activity as that of setting up, running, and maintaining systems. Further, Optner (1965) states that the systems view enables problem solving to concentrate on the process by which things are done, rather than on final outcomes since this enables us to get a greater insight to generalize on business phenomena.

We use the concept of a mobile service system to achieve the system view. A mobile service system can be seen as a process support system for mobile works consisting of a set of servers, some mobile clients (laptops, PDAs, mobile phones etc.) and human resources required to carry out a work process. For mobile service system design, the hard systems aspect covers for example system architecture, topology, connectivity, network, type of client(s), type of server(s), reliability, security, middleware to be used, etc.; the soft systems aspect covers, for instance, co-coordinating business processes that achieve improvements in the functioning of mobile workforces, which is aimed to maximize the performance of inter-related activities by supporting the business functions. As seen from the case studies, several problems are seen to recur when they are looked at as hard systems aspect only, which forces us to apply a soft systems thinking mindset.

Using the soft systems thinking mindset, we follow on (Checkland, 1999) and argue that solutions for mobile workforce activities should be considered at a higher level than that of physical operations. This is because there are many possible versions of the mobile service system to be engineered and systems boundaries and objectives may be impossible to define. Soft systems thinking is concerned with the services needed, as well as influences on organizational structure, business process, and individual, while hard systems thinking is concerned with selecting among alternative means of reaching a known end.

Hard system thinking and soft system thinking are both important in the development of services that support business processes, and should be balanced at the very beginning phase of a BEaMS project. This is because the soft systems thinking enables us to consider the human aspects of the services while the hard systems view enables us to incorporate the technological aspects of the solution. We argue that it is useful to make an initial understanding of a situation being studied to enable a selection of the best viewpoint from which to study further the problem situation. This leads to the following guideline for forming a starting point for the BEaMS effort.

Guideline 1: Form a systems view that balances soft and hard systems thinking at the beginning of the BEaMS project.

This guideline reinforces a systems view of the mobile solution and the business processes it supports, which allows for a change in relation to the industry trends without changing too much of the strategy. Considering that the mobile solution may require using technologies from different vendors and supporting different actors within a business process, there is need to look at the solution from the different perspectives of the stakeholders.

4.2.2 Apply a multi-actor system view: converge different value perspectives

According to Checkland (1999), in any problem solving situation the roles of problem owner and problem solver will exist and it should be made clear that these are roles and not individuals. Determining the roles and resources available to tackle a problem and getting the right answers establishes the *Weltanschauung* of the project, which gives meaning to the project. This worldview concept encourages the consideration of different perspectives from the different stakeholder roles. The development of mobile workforce solutions requires a detailed analysis of the stakeholders since the process involves different actors with different perspectives. Paavilainen (2002) introduces the concept of a value chain of mobile commerce, on which we can base the definition of the perspectives of the different actors involved in a BEaMS project. It begins with network infrastructure providers, providing e.g. cellular networks, internet connectivity, etc. In the second stage mobile commerce technology, such as payment solutions, security solutions, etc., is built on top of the network infrastructure, players on this stage are software vendors, transaction clearing centers, etc. Thirdly, content for mobile commerce is provided by business who want to sell their products and services via a mobile channel, e.g. music, ring tones, mobile banking, and the content is managed by content aggregators, such as news services, etc. Finally an interface to the mobile commerce is provided e.g. by mobile portal providers. Paavilainen explains strategies and business models showing opportunities for market players, for each stage in the mobile commerce value chain.

As a continuation of Paavilainen (2002)'s value chain model, van de Kar (2004) provides a comprehensive framework of the actors involved from a value network perspective. Jorstad et al. (2005) further specify the varied interests and perspectives of different actors. However, we argue that Paavilainen (2002)'s value chain and works that follow (e.g. van de Kar, 2004; Jorstad et al., 2005) do not cover organizations using mobile solutions to improve their businesses, as the recipients of the output of the value chain. Given that our focus is on mobile workforce solutions, we find it necessary to redefine actors within the context of a BEaMS project from a different angle. The case studies in chapter 2 show that a mobile workforce solution is delivered within a complex network where business units within and between several organizations have to work together to share necessary (technical and other) resources and capacities. For example, there is usually a strong involvement from mobile solution providers in BEaMS projects.

In this research we argue that the engineering of a mobile business solution requires the expertise provided by different types of mobile solution providers, among others identified by Jorstad et al. (2005) as: consulting firms, mobile network operators, mobile hardware/device manufacturers, wireless software vendors, and systems integrators. In practice, many mobile solutions providers perform more than one of these functions. For example, systems integration and consulting roles may be offered by the same organization, or by two organizations working in close partnership. More over, many larger consulting firms or system integrators are already moving beyond this joint capability to the provision of complete end-to-end mobile solutions and ongoing managed mobile services (Attwood, 2003). Consultants and systems integrators play an increasingly important role in facilitating the adoption of mobile workforce solutions. As a result, there is an emerging client-provider cooperation mechanism for BEaMS projects – client organization/problem owner on the one hand and the consulting firm/system integrator on the other.

We regard the roles and capabilities of the various types of mobile solutions providers as an important issue, because it helps us to clarify the roles and actors of a BEaMS project. We present an argument that although the roles of the actors/organizations involved in a BEaMS project may become simple due to the increasing capabilities of consulting firms, the required expertise in the roles for developing mobile solutions is still same. We argue further that it is still important to recognize and understand different perspectives in a BEaMS project, this leads he following guideline for landscaping the BEaMS effort.

Guideline 2: Recognize the different roles and capabilities of mobile solution providers and understand the different roles and perspectives they may have in facilitating the adoption of mobile workforce solutions.

The importance of this guideline is that it enables decision makers to incorporate and gain from the expertise of systems integrators and consultants in the initial phases of implementation, and it also enables decision makers to capture the various actor perspectives in the later stages of the project. However, some caution needs to be applied considering that some of the systems integrators and consultants may be willing to push technology solutions rather than solve business problems.

4.2.3 Mind the dilemma: technology push vs. business need

The identification of opportunities for "mobility" is increasingly becoming a core issue for many companies. However, many organizations, even though they may have taken up mobile solutions quite early, have difficulties realizing business transformation and business process redesign using mobile solutions. A main reason for this could be that "too much attention has been paid to commercially available and proved technologies and applications and, unfortunately, too little attention has been paid to the commercial conditions for success and, ultimately, value creation and competitiveness" (Christensen & Methlie, 2003).

Based on their research into the adoption of mobile technologies in business, Kohler and Gruhn (2004) indicate that companies frequently follow a technology-driven approach without precise knowledge of the potential benefits that may be realized. They further suggest that a systematic approach to mobile solutions is required if a verifiable economic benefit is to be created by using mobile technologies, especially in larger organizations with complex business processes.

The observations we made through the case studies presented in chapter 2 are consistent with the findings of Christensen and Methlie (2003) and Kohler and Gruhn (2004), who state that in today's mobile business transformation, "IT change" has been the major concern. This observation was further strengthened for us through an extensive discussion with twelve experts from different mobile solution providers at a workshop organized by Mobility Platform (www.mobilityplatform.nl), a research consortium of organizations in the Dutch mobile industry. Based on a discussion of the topic: What is their primary focus during a mobile solution project, we ended up with the following results. From the solution providers' perspective, the focus is primarily set on the cost and benefit of "IT change" at a customer organization, and therefore attentions are often at the very detailed level of IT, e.g. how to ensure the reliability and security of the network. All the experts involved in the workshop agreed with us that compared to IT change, "business change" does not gain enough attention during the development of mobile workforce solutions.

One driving force behind the "technology push" is that in many cases, mobile solution providers, e.g. IT consulting companies and vendors tend to dominate the question of evaluating the business benefits accruing from investment in mobile technology, and it is not surprising that they tend to over hype its true essence. Some business managers have fallen for these highly exaggerated stories without considering the critical points of mobile information systems initiatives in the companies' operating context (Kadyte, 2005).

Another driving force of "technology push" is the fact that the early use of mobile applications in automating business processes was primarily technology driven. In order to realize potential benefits of mobile technology, the design of mobile applications was driven by the possibilities offered by technology, namely availability of mobile devices and mobile connectivity. Process managers changed their processes to utilize the technology options available, rather than ensuring that technology worked within their business requirements and achieved all the business objectives (Unhelkar, 2006).

However, with the latest technological developments, we argue that processes can be enabled by mobile technology using a business-driven approach, where the mobile technology is just an enabler. Business driven means more focus should be given to business processes, e.g. concentration on the abstract level of business operation, and the detailed requirements and value of the new applications. We hence advocate for a “business process driven” approach for the deployment of mobile workforce solutions. This leads to the following guideline for reinforcing a way of thinking in BEaMS.

Guideline 3: Adopt mobile workforce solutions based on how the solutions support business processes rather than on the rapidly-changing technology.

This guideline ensures that the mobile solutions that are developed are in line with, and support, specific business process. The adoption of mobile solutions should be done in a systematic manner to ensure that all the relevant business processes to be supported by the mobile solution are covered.

4.2.4 Follow a structured approach

As we discussed in chapter 3, the primary benefits associated with deploying mobile solutions in a corporate setting include the potential to grow revenues, reduce operating costs, streamline business processes, enhance an organization’s competitive position, and improve relationships with the company’s stakeholder, including suppliers, alliance partners, employees, customers and shareholders. Therefore, the decision makers must be clear about a company’s strategic directions and how a mobile solution can assist it in getting there.

Moreover, it is important for decision makers to know that every organization operates differently within a set of environmental parameters. Hence a mobile solution must be customizable according the companies unique business requirements to generate appropriate benefits. Bearing this point in mind, decision makers can better avoid rushing immediately into a slew of available mobile solutions - all of which provide some benefit. Instead, decision makers need to pay more attention to which of these potential solutions fit the company’s strategy and business requirements best. We argue in this work that arriving at such a decision requires a structured approach that allows decision makers to determine their milestones and measure the progress of the project. We describe such a structured approach in a recipe in subsection 4.4.

In reality, some companies favor the rapid development of mobile solutions to address a current issue. Contrary to using a structured approach, rapid development does not usually require a thorough systems analysis. As a result, a pitfall of the rapid development of mobile solutions is that decision makers might jump onto opportunities that later turn out to be inferior to others, or worst dead end (Kornak, Teutloff, & Welin-Berger, 2004). The following guideline can be used to avoid this situation, and to assist decision makers to achieve their objective(s) when setting up a BEaMS project.

Guideline 4: Structure the approach to embracing BEaMS in such a way that it is possible to determine milestones and measure progress of the project.

This guideline encourages the decision makers to consider opportunities that fit best with their situation. To achieve this goal, the decision makers should use an approach that is firmly grounded in providing solutions to business problems. We argue that the approach can be grounded upon a business engineering perspective.

4.2.5 Realize the need for business engineering perspective

In developing the mobile workforce solution, we prefer the use of soft systems thinking to support the engineering of the solution. We make a general observation that mobile technologies are maturing, but their accompanying business applications lack a corresponding maturity. The barriers to the adoption of mobile solutions in organizations are not the technology challenges; hundreds of vendors now provide initiatives such as system integration, device management, routine support and maintenance. Thus, many packages and tools are available in the current market to help organizations deploy mobile technologies. The real challenge is how to instantiate available mobile technologies and form a business solution that is suitable for a specified organizational environment. To deal with this challenge, we can embed a business engineering perspective into the structured approach that is used to adopt mobile technologies.

Sol (1992) differentiates three perspectives when engineering an organizational system, micro, meso and macro. We follow this division, and argue that the key requirements for engineering mobile workforce solutions are related to alignment at these three organizational levels. The first level constitutes a micro-alignment between the mobile technology and employee fit; it deals with mobile technology adoption over time and emphasizes the need to provide usable mobile services that support the employee's choices and working needs. The second level corresponds to the classical intra-alignment of mobile technology with the core business processes. It is expected that mobile technology investments will drive critical business processes towards achieving excellence. Finally, the third level considers an inter-alignment between mobile technology and organizational capabilities at the interface with customers and partners. In our view, the second level of alignment is essential for BEaMS projects though the other two levels of alignment are also necessary in achieving best business practice in the dynamic and complex business environment.

Through the case studies presented in chapter 2, we learnt that it is hardly the case that business processes can be radically changed by leveraging mobile workforce solutions. An all-embracing approach that includes all alignment issues at the three organizational levels might be unrealistic. However, using a business engineering perspective to engineer the solution provides the possibility to add new business processes that may arise in the future. The following guideline is based on this discussion.

> Guideline 5: Apply business engineering principles to determine the requirements for a mobile solution with the aim of improving overall performance and creating additional value of the mobile solution to the business processes.

This guideline enables the decision makers to use the best engineering practices to achieve the goal of developing mobile solutions or to improve the overall performance of existing solutions. It supports the decision makers in understanding the strategic business goals and objectives that determine the additional value that is created to a business process through the application of a mobile workforce solution.

4.3 Initiating guidelines

Initiating is about forming a project team and building consensus. In this section, we provide tactical guidelines for dealing with concrete issues that reinforce a way of controlling for the BEaMS project. They are in line with the landscaping guidelines presented in the previous section.

A BEaMS effort can be set up as a project, defined as a specific, finite task which has to be accomplished by a contemporary arrangement of people within a fixed schedule and within fixed costs. However, the challenge is in implementing the project in a multi-actor environment, and we argue that decision makers at the tactical level should be supported in handling issues that will arise in such an environment.

4.3.1 Involve right participants and clarify their roles

As we discussed in subsection 4.2.2, a BEaMS project should involve actors from different organizations. Given that most organizations are not expected to have all the required expertise in-house, it is important to form a multi-disciplinary team of experts from consulting firms, who work in close interaction with a limited number of internal stakeholders, e.g. operation managers, mobile workers, information managers, and functional administrators. The external experts should have extensive and comprehensive knowledge of how to gather appropriate business requirements and how to design mobile solutions. Further, we argue that it is of great importance to ensure that the right participants are targeted for involvement in engineering mobile workforce solutions at the tactical level.

We advocate for the use of consultancy in designing the mobile solution, which further strengthens our argument that there is a need to involve people from different organizations, e.g. business analysts, service designers, operational managers, mobile workers, project leaders, etc., for a BEaMS project. This is based on the fact that solution providers have the required expertise, and solutions that are developed in-house tend to be rather expensive as witnessed by IT-based solution today (Attwood, 2003). The experts from consulting firms are divided generally into business analysts and mobile service designers.

Business analyst: this is the person responsible for analyzing the business processes and determining situations under which a mobile workforce solution can be implemented. Their role is to develop business analysis models which are used by the mobile service designer to achieve the mobile service solution. In the studio, they need to be supported in coming up with accurate models of the business process to be supported by the mobile solution. Business analysts play the role of providing a link between the user community and the technical solution designers. They should understand how mobile technology can serve business processes. They are responsible for capturing business requirements and translating them into service requirements.

Mobile service designers: this actor plays the role of realizing the mobile service solution as presented by the business analysts. They receive the conceptual models for BEaMS and turn them into working solutions. They are responsible for validating the mobile services before they are delivered to the mobile workforce. Within the studio, they need to be supported with tools that enable them to focus their design and to make decisions about how to implement the models delivered to them by the business analysts. Mobile service designers should have a technical background in mobile applications and systems integration, and are responsible for translating the service requirements, delivered by the business analysts, into systems requirements.

The internal stakeholders are divided into three types: mobile worker, project manager, and the organization director.

Mobile worker: The narrow definition of mobile worker remains same as we defined in Chapter 1. In most cases, mobile workers are the end users of the mobile services, and are most visible at the initial phase of a BEaMS project. However, in some cases, the work of a mobile workforce has to be accomplished with the support of all staff, e.g. a dispatcher or a coordinator in the back office. Therefore, it is necessary to view the concept of a mobile worker in a broader scope and in the specific context. It may refer to all the potentially influenced workers in the targeted operational business processes. Within the studio, this category of actors needs to be supported to define their needs from a given business process since they are the end users of the mobile services being designed.

Project manager: this actor is responsible for facilitating the mobile workforce solution, and plays the role of managing the whole process. The project manger plays the role of ensuring that all resources required to achieve the optimum solution are in place. The project manager leads the design process by setting the agenda and guiding the activities that take place within the project. A project manager typically handles administration and governance, time lines and budgets, and is responsible for managing the planned deliveries of a BEaMS project. .

Organizational director: this actor represents the decision maker at the highest level of the internal organization. An organizational director may be the executive of a company, and their interests are in return on investment, or strategic benefit. He or she is influential in defining the overall mobility strategy, and approving the BEaMS project. The organizational director provides the vision for the mobile workforce solution project from the strategic level and is interested in the outcomes of the project.

In the recipes and suites, to be discussed in next sections, we will mainly consider the interaction between business analysts, mobile service designers and mobile workers as the targets. The audiences to benefit most from the recipe and the suite will be the business analysts and mobile service designers. We intend to support their work. In another words, the use of the studio will ease their mobile solution engineering efforts, and enhance their decision making capacities regarding models, designs, etc. The ultimate benefits will be for entire project teams including the project managers and the organizational directors.

We recommend that at least one business analyst is involved in a project, whose main focus is on process analysis, and at least one mobile service designer whose main focus is on mobile service design. Both actors should have a good knowledge in the field of mobile workforce solutions and maintain communication about each other's activities. Though in many cases the roles they play are not clearly defined, or are possibly ever changing, we can briefly classify the actors according to the simplified model shown in figure 4.2.

The following guideline is based on the preceding discussion, and made from the perspective of involving the right participants in the BEaMS project.

Guideline 6: Involve at least one business analyst and at least one mobile service designer in the project, and prioritize the roles of these two actors in process modeling.

This guideline focuses on finding a balance between extensive discussions by the stakeholders, and encourages them to improve business processes in a structured manner that considers the mobility opportunities versus the need to arrive quickly at an answer to a problem a company is facing. However, the organizations have to be aware of the high costs of consulting expertise, and should put in place a guiding framework within which to carry out the mobile solution engineering process. The level of support for each of the actors that were identified as participants in the BEaMS project is presented diagrammatically in figure 4.2.

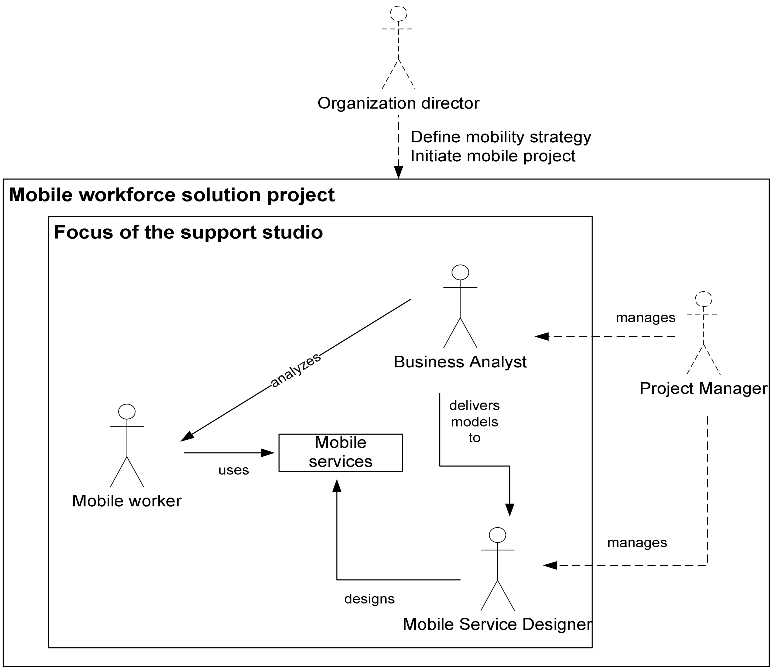

Figure 4.2 Simplified structure of a BEaMS project

4.3.2 Adopt an adaptive project management process

Project management is one of the most basic forms of management used to control design projects. In project management it is assumed that problems and solutions are reasonably stable within certain limits and that management techniques like clear goals and targets, a time schedule, a clear framework and a prefixed end product can be used.

Positioned versus project management, process management (de Bruijn et al., 2002) is focused on identification and implementation of changes, by creating a sense of urgency, openness and integrity, protection of core interests and core values of parties, incentives for continuation, and process type arrangements to facilitate sufficient content. It also stresses the need to help involved actors focus on following agreements, meetings and negotiations. However, it is important to note that just like project management, process management does not address all project management problems in a multi-actor setting.

Sol (1992) argues that the adaptive strategy is the most appropriate strategy for design projects. In this strategy a design project is regarded as an adaptive process of learning for both the consultants who are actually responsible for solving the problem and the stakeholders of the organizations involved. Both groups can add specific knowledge and learn from each other. We agree with Sol (1992) that an adaptive strategy is very important for BEaMS project. Therefore, we argue that there should be a balance between project management and process management techniques to cope with the dynamic characteristics of BEaMS projects.

Guideline 7: Apply adaptive strategies to the project and process management processes for the purpose of controlling a BEaMS project.

The importance of this guideline is to ensure that we do not apply rigid methods to the management of the mobile solutions project. The approach used to manage BEaMS projects should allow for flexibility considering that it may take time to deliberate on issues to such an extent that by the time of implementing a mobile solution there would be newer technologies on the market. The method should not focus too much on command and control, but instead provide for innovativeness to take centre stage, while enabling the participants in the project to communicate effectively with each other.

4.3.3 Facilitate interaction among participants

The involvement of several actors within a BEaMS project requires an easy way to communicate about the activities of each stage. Participation is consequent upon the fact that progress is dependent on developing shared mental models between participants (Vidgen, Rose, Wood, & Wood-Harper, 1994). This means that the conceptual models and empirical models should be understandable and accessible to every participant. For example, because process modeling founds the basis for the rest of mobile service design and development, it is necessary to inform service designers who have to work with the process models about the modeling process. A good way to do this is to involve these two actors in the process modeling and analysis stages. For conceptual modeling we argue for the use of graphical representations, while for empirical modeling this can be accomplished, for example, by using animation facilities, which can visualize the functioning of the dynamic models (Babeliowsky, 1997). Through the case studies, we learnt that the business processes for the mobile workforces are very dynamic, and that there is a need to capture each of the processes effectively to support the decision making. This leads to the following guideline.

Guideline 8: Use a dynamic modeling approach to develop process models that facilitate the communication and interaction among the decision makers.

The importance of this guideline is to ensure that every participant is aware of the processes being targeted, so that they can contribute to the design of the solution. This also ensures that the environment is conducive to capture all the stakeholders view points and incorporate them into the solution. However, considering that the decision space may become large depending on the number of problems being solved and the number of participants involved in providing answers, there is need to provide scope and context for the problem and to arrive at effective communication.

4.4 Recipes

In this research, we argue that while the landscaping and initiating guidelines of the support studio are directive, the recipes are more operational and reinforce a way of working. Decision enhancement needs recipes; otherwise it remains largely ad hoc and unsystematic (Keen & Sol, 2007). The recipes of our support studio provide precise scripts but leave open options for variations in detail, and provide the sequence of steps to be followed to achieve a BEaMS effort. The recipes of our support studio centre on the design of mobile workforce solutions in a multi-actor situation, with the aim of supporting each of the actors in performing their mobile service design activities. The recipes described in this section are the result of integrating the directive guidelines in landscaping and initiating components previously described, consistent with the activities of the 3 phases presented in figure 4.3. The recipes are derived from the concept referred to as business engineering by Meel and Sol (1996), which was discussed in section 3.3.2. The focus of the BEaMS project is on the effective analysis and design of business processes. As we noted in section 3.3.2, there is a lack of a comprehensive, scientifically grounded design methodology to structure, guide, and improve organizational design efforts. The recipes presented in this section are aimed at providing some structure to the way of working in a BEaMS project.

Focus of use
Before we introduce the recipes in detail, it is necessary to provide a conceptualization of the way in which a BEaMS project is conducted based on our findings from inductive case studies in chapter 2 , and to highlight the focus of using the recipes. Figure 4.3 is used to illustrate the procedures and activities of a BEaMS project at an abstract level. From the figure, we can see that the BEaMS project is divided into 3 phases.

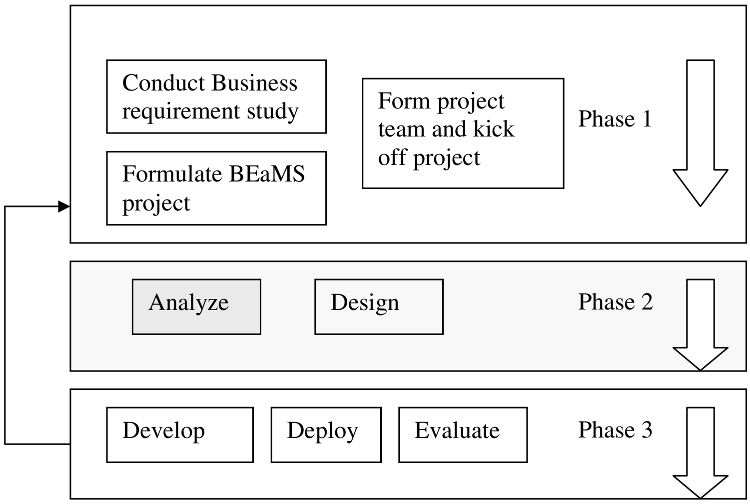

Figure 4.3 Procedures and activities of a BEaMS project

The first phase is concerned with performing a business requirements study, creating a strategy with which to formulate the BEaMS project, and forming the team to carry out the project. The purpose of this phase is to provide an understanding of the business challenges to be faced in the project and to facilitate the achievement of the project goals by supporting the service designers and business analysts.

The second phase is concerned with conducting a thorough business requirements study for the BEaMS project with a focus on process design. The purpose of this phase is to put into operation the results obtained through the activities in phase one, and to ensure successful transition to the design of a mobile solution.

The third phase is concerned with developing the mobile solution and deploying it in the organization. The solution may be developed using rigorous software engineering principles and methods in such a way that supports the business process identified and designed through the previous two phases. This phase also contains the activities related to deployment of the solution among the mobile workforces. After developing and deploying the solution, there is need to evaluate whether the mobile solution is in line with the roadmap formulated for the BEaMS project in phase 1. The purpose of this evaluation is to determine if the anticipated benefits have been achieved. Although the phases presented in figure 4.3 are sequential, the activity blocks presented in each of the phases are not. Instead, the activities are often carried out in an iterative manner, and the design team does not have to carry out all the activities, depending on the project and state of maturity of the organization when engineering mobility in their business processes.

Given the scope of this research, we limited the focus of the recipes to the first two phases of a BEaMS project. For the activities of the first phase, we provide recipes on how the business requirements study is carried out, and how to formulate a BEaMS project. For this phase, we also provide recipes for establishing the project team and kicking off the project. For the activities of the second phase, we provide recipes for carrying out a business analysis with a focus on process and service design issues. The activities in the third phase are concerned with development, deployment, and evaluation of the mobile workforce solution, and will be not discussed in detail in this research. We argue that such activities are quite similar to those used for standard IT-based solutions today, and refer the reader to (Chaffey & Wood, 2005) for a discussion of detailed methods and guidelines.

Context of use
In practice, the activities in phases 1 and 2 should be led or carried out by business analysts and mobile service designers. It is critical to maintain consistency between the activities carried out by these two actors. This view follows on Giaglis et al. (2005) who indicate that a common problem for business engineering is that business analysts and IT professionals traditionally have had distinct roles within organizations, each equipped with their own tools, techniques, skills, and even terminology. There is very limited support for predicting the consequences that changes in one organizational facet, business process or IT, will have on the other. The challenge is often how to create cohesion between the two actors, and we argue for the application of recipes (and suites) as a solution.

The context of applying the recipes (and the suite) with the aim of creating cohesion between business analysts and mobile service designers is presented in figure 4.4. From the diagram, we can see the business analysts and mobile service designers develop the initial models together based on their perceptions of the organization, and use the recipes (and suites) to gain a dynamic modeling perspective. The results of using the recipes (and suite) are applied to design a mobile solution to support the organization system. The details of the recipes are presented in this section while the details of the suite are presented in section 4.5 and chapter 5.

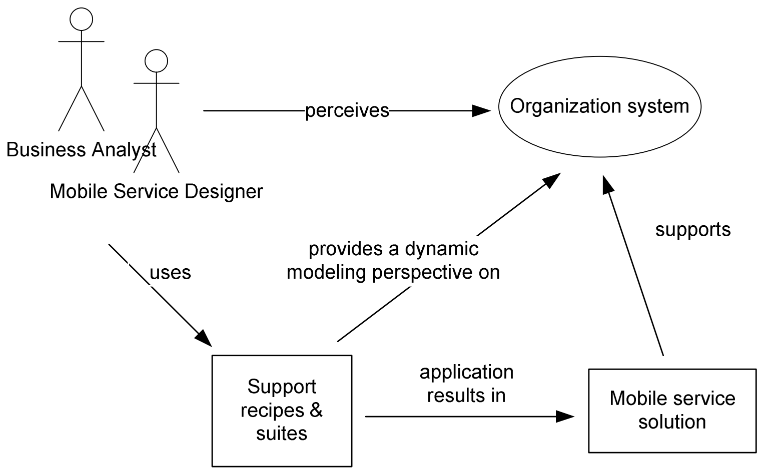

Figure 4.4 Context of applying the recipe and suite

4.4.1 Conduct business requirements study

Enterprises need to have an understanding of the specific benefits and challenges of implementing mobile solutions. Successful decision makers should adopt mobility through an iterative process to achieve optimal return on investment. We argue that the following steps, which form the recipes for the first phase of the BEaMS project, should be followed.

Step1: Understand the drivers of demand for mobile services in the enterprise
There are several factors driving the move towards mobile services in an enterprise, and it is important to understand the main drivers since this helps the decision makers to determine the appropriate solution for their organization. For example:

- demand for greater productivity from senior managers who are themselves more mobile and have a workforce that is increasingly unlikely to be connected to a single desktop.
- equipment suppliers and systems integrators have begun to produce horizontal solutions for corporate customers, making implementation of mobile connectivity to corporate networks both cheaper and less complex.
- new handheld equipment coming to market is designed to help computing on the move and hence make it easier for employees to work away from base.
- global mobile services network providers are making a major push to offer mobile solutions to key corporate customers. Mobile operators are beginning to step up efforts to win and keep corporate contracts and to show a greater understanding of the needs of their larger business customers. Currently we also see national and international mobile data connectivity charges continuing to fall, and services offering greater bandwidth and 'always-on' connectivity are beginning to emerge.

In line with landscaping guideline 3 presented in subsection 4.2.3, we argue that the drive for adopting mobile solutions within an organization should focus on applications, services and equipment that are used internally by a company to support their business processes. This would avoid adoption of solutions based on technology push.

Step 2: Understand the categories of mobile workforce solution functionality
Mobile workforce solutions vary in the degree of automation and robustness, as do the job responsibilities of field service workers vary by vertical industry and company. This makes it necessary to understand thoroughly the different categories of solutions before determining the applications that suit an organization. To support the understanding of mobile workforce solution functionality, we recommend the application of the three general categories of mobile field service solutions based on sophistication, type of connectivity, and depth of information delivered to the field user, as identified by (Signorini, Jones, & Kingstone, 2002) as follows.

- *Entry-Level*: solutions in this category include basic dispatch and communication functionality, with relatively light data-delivery capabilities. An entry-level solution may be appropriate for a particular organization's service needs - for example, in basic break/fix service in verticals such as utilities or home appliance repair, where rapid communications and dispatch are a priority, and access to detailed customer history or product information is usually not necessary. With a basic system, service calls are closed out via a phone call or message sent from the field technician or by another manual process when the technician returns to the office, rather than through an automated function on a mobile or wireless device.

- *Mid-Range*: solutions in this category offer more robust application functionality for the field technician. In addition to basic dispatch and wrap-up functions, solutions in this category may offer limited inventory management functions, and may include some customer history and basic repair instructions. Mid-range solutions typically come with some pre-built vertical-specific workflows, but have less out-of-the-box functionality than high-end solutions.

- *High-End*: solutions in this category deliver rich data to the field, and are customized for specific industry verticals. Features common to this category include the ability to retrieve detailed inventory and parts-availability information, access to step-by-step diagnostic and repair instructions, and detailed history for the customer, site, and even the specific device. Vendors of these solutions may focus heavily on a particular vertical, or may offer separate, highly customized versions for a variety of different verticals.

In summary, from the application of the three general categories of mobile workforce solutions identified, we state that if an organization is in the early stages of field service automation (moving from a paper-based process), or because they have not committed the financial and technical resources necessary to implement a more sophisticated solution, the functionality of their mobile solution may be categorized as entry level. Since always-on wireless connectivity is still rare, and is generally impractical for higher bandwidth functions, solutions generally consisting of a thicker client application on the mobile device are categorized as mid-range. If the mobile solution generally has extensive pre-built customization for specific verticals, it is categorized as a high-end solution.

These categories represent both the range of available choices and the typical path of application evolution, and should be used to understand the functionality of a mobile solution. It is necessary to understand the business processes thoroughly to determine the appropriate functionality of a mobile solution for the organization

Step 3: Understand how to get value from mobilizing the business

Based on an initial understanding of the functionalities of mobile workforce solutions, the decision makers need to think of how to derive value from "mobilizing" their businesses. One way to capture the value of mobile technologies is to look at some of its features, such as ubiquity, reachability, security, convenience, localization, instant connectivity, and personalization (Chae, Kim, Kim, & Ryu, 2002; Kadyte, 2005).

Nah et al. (2005) suggest another way to make the value explicit for companies that want to incorporate mobile solutions in their business processes. Nah et al. (2005) consider the following as the most important fundamental objectives: efficiency, effectiveness, customer satisfaction, security, cost and employee acceptance. Further, it was observed by (Meijer, Samuels, & Terpstra, 2002) that mobile worker's acceptance of solutions based on mobile technologies follows the known principles of diffusion theory presented in (Parker, 1994), where social context, risk and divisibility are key factors. Many mobile solutions have failed to produce the expected results due to neglect of these key adoption factors. It is important to note the possible pitfalls when capturing the value of a mobile workforce solution.

We recommend focusing on the business processes, and argue in line with the work of (Leung & Antypas, 2001), that decision makers should look at the business value of mobile applications and technologies in two main areas: operational efficiency, through the ability to distribute information to the workforce remotely; and customer satisfaction, through the provision of an additional channel through which interactions can occur, in effect adding to the customer value proposition.

Step 4: Understand costs and benefits of mobile workforce solutions (tangible and intangible)

The usage of mobile services implies tangible and intangible costs and benefits. However, we argue that these costs and benefits should be looked at from the systems view presented in guideline 1 in subsection 4.2.1. Adopting such a view would ensure the design of mobile services that add value to the way business processes are performed. Deighton (2003) indicates the possible costs to achieve the potential benefits of mobile workforce solutions. Wang et al. (2005) summarized the costs and benefits for workforce solutions and we further extend these tangible and intangible costs and benefits for mobile services in general, and present them in table 4.1.

	Benefit	**Cost**
Tangible	• Save time or effort • Business process efficiency/productivity • Information accuracy- reduced correction costs • Asset tracking • Eliminating fixed infrastructure	• Capital hardware, device, servers, software • Operational cost: especially airtime • Software licenses • Support and management • Integration e.g. with legacy systems
Intangible	• Efficiency: convert dead time into useful time • Happiness: always connected and entertained • Employee quality of life e.g. flexibility, in touch with family • Customer satisfaction • Brand image & value • Flexibility & agility • Accessibility, presence and responsiveness	• "Always on" stress • Destruction of communities of practice • Complying with legislation e.g. working hours • Generational attitudes and resistance • Hinder in public places by ringing phones, loud talking people • Privacy

Table 4.1 Benefits and Costs of Mobile Services

Based on the discussion regarding the costs and benefits of mobile services and the information presented in table 4.1, we suggest that it is necessary to understand the tangible and intangible costs and benefits of a mobile workforce solution and use them to justify the development of the mobile solutions. We prefer to use a systems view of the mobile solution as presented in guideline 1 in subsection 4.2.1. This is based on the argument that conventional return on investment calculations may not always be appropriate for mobile applications. The BEaMS projects should be treated as any other IT project with an identified return on investment and defined metrics for determining success. We recommend, where possible, the estimation and quantification of the intangible benefits.

4.4.2 Formulate the BEaMS project

Organizations have to devise effective strategies to make enterprise mobility successful. The landscaping guidelines 2 and 3 in section 4.2 can be used to help decision makers understand the roles and activities of the BEaMS project on which to base the development of solutions. While formulating the BEaMS project, it is important to apply lessons learnt from current attitudes, policies, and practices, by looking at how these impact both employees and businesses. We argue for the use of a process driven approach to BEaMS as a means to learn from current practices. Understanding the business processes enhances the formulation of strategy, and is related to the process driven nature of the solution as presented in the landscaping guideline 3. To formulate the BEaMS project, we recommend that the decision makers incorporate the following factors to design mobile solutions.

Formulate means for evaluating current business processes. Implementing a mobile service solution presents an opportunity to re-evaluate and improve business processes that support field workers. The decision makers should be provided with means to enable them to evaluate the current business processes, with the aim of eliminating situations in which automation is done for all current processes. Instead, the means for evaluating the current processes should focus on those processes in which mobile solutions can add value.

Enable the decision makers to focus on the mobile service as part of the overall IT strategy. The implementation of a mobile service solution should be undertaken with careful consideration of how both the hardware and the applications will complement the overall IT strategy. However, mobile service functionality should not just be treated as another component to be checked off during the process of implementing a broader multi-channel system or other enterprise IT initiative. The project team should be given a set of steps that can be followed to ensure that the mobile solution fits in well with the IT strategy of the organization.

Support the selection of the right category of solution.. Decision makers should be assisted in making choices regarding whether a customizable "toolkit" or a highly specialized application makes more sense for the particular needs of the organization. Depending on which one is best for the situation, the series of steps taken to reach the decision should be recorded and if possible, replicated in other projects.

Establish a framework through which information needs can be understood. By understanding the true benefits of real-time information, decisions regarding the level of connectivity required can be established. Even if there is a requirement for large extensive connectivity, network limitations may present a significant barrier. The project should be formulated in such a way that solutions can be designed with both connected and disconnected capabilities.

Provide means for assessing business processes and internal functions. The decision makers should be provided with means that enable them to identify relevant activities, participants, and information flows that will gain the most from mobilization. Quantify these benefits using tangible metrics and calculate and estimated payback period as suggested in step 4 of subsection 4.4.1. The identification of relevant activities can be done using the guidelines presented in the previous sub-section.

Provide support for testing proven technology before investing. It is important to provide the necessary support that enables the decision makers to invest in proven technology. This can be done through learning from the solution providers' references, preferably drawn from the same industry and with similar business processes. If a solution is preferred, it is important to implement it in a single department or business unit first, setting clear goals and success benchmarks on which organization wide implementation can be based.

When formulating the BEaMS project, there is need to ensure that the project allows for decision makers to select the mobility solution that best supports the organization's business processes and is the right one for implementation in that particular organization. This will enable the organizations to avoid using technologies that run in parallel to their goals, as supported by our arguments for guideline 3 which enables decision makers to avoid the dilemma of technology push.

We argue for the need to use a structured approach to BEaMS as presented in landscaping guideline 4 in subsection 4.2.4. This enables the decision makers to design a mobility roadmap for the BEaMS project. The purpose of the mobility roadmap is to ensure that the strategy defined in the earlier stages of the mobility project is implemented in a structured manner. It should be dealt with at a highest level of the organization since the introduction of a mobility solution will have an effect on the whole organization. The mobility roadmap should enable decision makers to do the following.

Get mobility into the corporate agenda

Mobility strategies are necessary to reduce delays incrementally from work practices and processes, and should therefore be put on the corporate agenda of the organization. The long term strategy for implementing mobility in the organization should contain clear goals and milestones.

Many organizations deploy mobile technologies in specialized niches, such as field or sales force automation, to gain short-term cost savings or productivity benefits. In the short-term, this results in several operational benefits, and can be used as a guide for managing the adoption and use of wireless services. However, considering that the technology is changing rapidly, and many decisions may be changing in the short term, there is need to continue thinking about a long-term mobile strategy. The long term strategy should enable organizations to develop short term strategies that enable them to align their business process in a systematic manner.

Implement the mobile solution in stages

In those enterprises where vertical applications have a well-defined operational and industry specific focus, the provision of wireless technologies can provide obvious and measurable results and it is relatively easy for systems integrators to offer solutions to 'extend the reach' of the enterprise in fast and simple projects. This activity is already taking place and forms the backbone of many current wireless initiatives. Such initial implementations can help kick-start broader, longer term projects. Beyond these immediate wireless systems integration initiatives, however, lie the longer term planning issues.

Handling these long term planning issues enables the decision makers to focus their efforts on defining attainable targets for implementing the mobile solution. This relates to implementing the results achieved in applying landscaping guideline 4, and stresses that before deploying the solution, the decision makers need to be able to identify what the organization will look like after selection of a given mobility solution. To complete the activities in phase 1 requires setting up of a team that monitors and controls the mobility solution strategy.

4.4.3 Form the project team

Forming a team to implement the BEaMS project involves the determination of the number of people and the skills that are required to ensure successful implementation. A key factor for successful deployment of the mobility solution includes the development of a solid team control strategy. Teamwork is important in the development of a mobility solution because it is a complex undertaking that requires a variety of skills, especially considering that many organizations have the resources and skills to complete the task on their own. This means that decision makers should be able to evaluate the business processes and assess the benefits of partnering with others to achieve better results. In order to achieve this, we recommend that the following steps are followed.

Use experienced solution providers. The BEaMS project team should combine experienced solution providers with internal consultants and mobile service designers who are involved in introducing mobile workforce solutions. This is in line with initiation guideline 6 presented in section 4.3.1. The wireless requirements for field service differ from extending e-mail and other IT applications to mobile professionals, or providing information to customers via handsets, which makes the BEaMS project to call for people with extra skill and experience. The complexity of mobility solutions dictates that organizations team up with experienced solution providers to help bring the strategy to fruition faster than when working with vendors who do not have experience in field service deployment.

Highlight role of mobile workers. The formation of the project team should always leave some room for the mobile service end-user involvement. It is critical to involve the right people at the right moment in a design process. Given the complexity of business problems and technology opportunities, the formation of the team should ensure that more of the right people are involved in a BEaMS project. In addition to ensuring that all perspectives are captured, broader participation may foster broader acceptance of the outcomes of mobile workforce solution design. This is also related to initiating guideline 7 presented in section 4.3.2. However, the need for broader involvement implies that the use of fixed time periods and “command and control” methods characteristic in traditional project management may no longer be sufficient. We recommend that to address this challenge, the decision makers should make use of techniques from process management to support collaborative efforts, and to include the mobile workers in the BEaMS project.

Provide adequate access to the organization. The project team should consist of people who have adequate access to relevant parts of the organization. If they already do not have the access, arrangements should be made to enable them to get access that would facilitate in carrying out their work activities. It is important that the business analysts and mobile service designers are granted access to the relevant personnel and business processes in an organization during the BEaMS project. This unlimited access will enable them to perform a thorough analysis of the business processes that are to be supported by the mobile workforce solution, and ensure that they are able to design solutions that cover all the important aspects of an organization.

Some methods that can be used to facilitate activities in phase one can be referred to appendix 2.

4.4.4 Carry out a thorough analysis, with a focus on process design

Business process redesign and changes in supporting infrastructure are necessary first steps to ensure successful transition of workforce solutions that can be potentially enhanced by the capabilities provided by mobile technology (Kadyte, 2005). This is part of the implementation for landscaping guideline 5 and initiation guideline 7, which recommend the use of business engineering and process management techniques. This recipe is also related to the suite, details of which are discussed in chapter 5. The essential steps of this activity are summarized as follows.

- Step 1: identify existing core business processes
- Step 2: assess potential for improvement by the opportunities of mobile services
- Step 3: map alternative business processes based on the results of mobile services
- Step 4: analyze alternative business processes by simulation
- Step 5: deduct general conditions and requirements for services and systems design

These steps are developed based on the high level requirements to conduct a business process simulation study, as discussed in subsection 3.3.3.

Step 1: identify existing core business processes

With the initial objective gained from phase 1, the core business processes that are targeted by the project need to be focused. Landscaping guideline 5 in section 4.2.5 states that we should apply business engineering principles to determine the processes that need to be incorporated in the mobile solution. Since not every business process is suitable for improvement through the use of mobile workforce solutions, business processes need to be carefully identified and modeled. For the purpose of identifying business processes, many techniques can be used, from simple graph drawing from sketch, to standard modeling language e.g. UML, and to advanced and systematic modeling package, such as ARIS which was used in the Railpockets Connection case presented in chapter 2. Choosing an appropriate technique is always dependent on the skills or the preferences of business analysts, as well as the level of details the models need to represent. The resulting models will be used as a starting point for the steps to be followed.

The importance of modeling the current business processes is usually recognized immediately, but getting all the required information may be a time consuming process. It is only if the business processes involved have been modeled before, that it is easy to get as-is models finished quickly and then start the analysis process with the models directly. If they have not been modeled before, a cycle of internal discussions has to be started. Though it may slow the whole analysis process, it is wise to carry out a time-and-motion study on the mobile workers' activities, because it helps to learn the real, rather than theoretical, processes.

Step 2: assess potential for improvement by the opportunities of mobile services

It is necessary to study the current business processes with the existing IT support system, and to look at the business processes that are to be delivered through the mobile solutions. With the output from phase 1, business analysts and service designers should already have known (more of less) implicitly the possible opportunities of mobile services for the organization. The focus here should be on reflecting (representing) the opportunities in a more explicit manner.

It is important to understand what constitutes the effective design of a business process. Business processes typically have a specified duration and place, a beginning and an end, as well as inputs and outputs. The focus of this step is on removing activities that do not add value and ensuring the efficiency and effectiveness of those activities that do add value. It is worth mentioning that, to get this step done successfully, business analysts and service designers need to work closely to get views and to share ideas. Service designers should contribute the solutions that are technically feasible in the context, and business analysts should be able to steer on the value of the solutions to the business processes. This step results in some initial solution ideas, as well as the related potential results. To ensure that this step is applied effectively, there is need to include at least one business analyst in the process of assessing the potential improvement, following on initiating guideline 6 in subsection 4.3.1.

Step 3: map alternative business processes based on the potential results of mobile services
With a more clear vision of the potential results that the mobile solutions may offer, business analysts need to gain more qualitative and quantitative analysis in depth. In this step, we recommend the use of standard modeling principles to illustrate the business processes in a more formal way, so that the work activities, actors, and input and output objects can become more visible. Attention needs to be paid to adding location, time, and information dimensions during the modeling process. The resulting models should allow the business analysts and designers to explore different experiments by changing the relevant parameters.

Step 4: analyze alternative business processes by simulation
The business analysts need end-to-end visibility of the business processes to analyze the performance of process that are to be influenced by mobile solutions. The involvement of business analysts is presented in initiating guideline 6 in section 4.4.3. Simulation plays a key role in facilitating this step. Using simulation enables analysts and designers to understand and manipulate dynamic behavior of complex business processes, and further enables them to conduct quantitative analysis. The use of simulation should help the business analysts and designers to select from various alternative scenarios for designing mobility solutions. We will extend our discussion on this topic in section 4.5 and chapter 5.

Step 5: deduct general conditions and requirements for services and systems design
Building on the previous steps, business analysts, service designers, and other decision makers, may come up with an optimal solution for future design. The general requirements for mobile service systems design can be deduced and formulated. Service designers play a key role in leading this step. When deducing general conditions and requirements for mobile service systems design, it is important to follow the soft systems approach as presented in landscaping guideline 1 in subsection 4.2.1. We argue for this approach because the design of mobile service systems is an extremely complex activity, encompassing several different disciplines. The mobile services field is also characterized by risks and uncertainties involving future events that are difficult to predict (van de Kar & Verbraeck, 2007).

In conclusion, to carry out thorough analysis and focus effectively on designing the mobile solution, we argue for the use of a business engineering approach to identify and simulate the current business processes that a mobile solution could be used to support. In chapter 5, section 5.4, we will illustrate how the steps can be carried out with the support of a simulation suite in the given contexts.

4.4.5 Design the mobile workforce service system

After the analysis of the business processes has been carried out and the requirements for designing the services and the service system have been determined as presented in the previous section, the next logical step is to design the service system that is used to support the mobile solution. A mobile solution should be able to simplify business processes by extending the data to the point of work, and enabling the smooth transfer of data back to the main office. As more mobile workers incorporate this solution into their workflow, the uses and benefits of convenience, efficiency, and interoperability then can be increased. We argue for the use of a structured approach to designing the service system such as Mobile Arena developed by LogicaCMG based on their experience in designing mobile solutions, as presented in figure 4.5.

Using the Mobile Arena enables the designers to differentiate between the users of the service, the devices, the application, and the network technology. Each quadrant in figure 4.5 has a great influence on the possible functionality of the mobile workforce solution design and ultimately, the end-user experience when using the mobile solution. The Mobile Arena covers most issues guiding an effective mobile solution design. We recommend that the design of each mobile solution should not necessarily consider every quadrant, and that the design should be approached from the context of the organization.

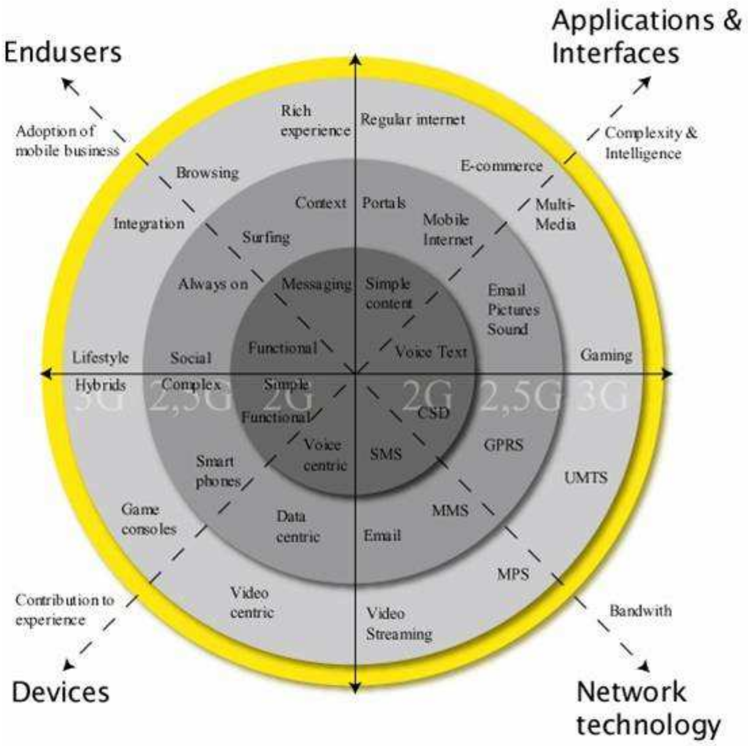

Figure 4.5 Mobile Arena developed by LogicaCMG

Cope with characteristics of mobile environment

Service delivery for workforces based on mobile networks is rapidly gaining popularity. Kalakota (2002) indicates that "in fact, mobile solution deployment is gaining speed as different pieces of technology, particularly network software, mobile devices, and new applications start coming together". As a result, the next generation of mobile solutions "based on lower-cost infrastructure is rapidly advancing to solve widespread business problems". Kalakota further points out that next generation of mobile enterprise solutions focus on enabling processes, not tasks; are more standardized, not customized; emphasize production systems, not prototypes; and drive return on investment via process improvement at the employee and enterprise level.

The effective design of mobility solutions can make significant differences especially when one considers that such solutions may be faced with problems that do not necessarily affect workers in wired environments. The infrastructure related problems such as (partial) loss of access to data, or loss of telecommunications signal are real, and effective design processes may improve the impact of the mobility solution.

In designing the mobility solution, distracting events that always take place around users who are not in a stable environment at home or in the office should be taken into consideration. While carrying out their work activities, mobile workers may find themselves in environments that are inherently characterized by vulnerable infrastructures and the ever changing context of the workers. These situations require the development of a mobility solution that supports the routines of the users (thus one that is "process engineering oriented" instead of "task engineering oriented") and that aims for solutions that emphasize the "usage" in addition to being scalable and replicable. This implies that consideration of the users' context is a key issue in the design process, and we refer the reader to (van de Kar, Muniafu, & Wang, 2006) for further discussion on this topic.

Ensure value and quality of mobile services

The service system for the mobility solution is aimed at providing value for its users. Van de Kar and Verbraeck (2007) observe that this added value is realized when users *can* use the service system, and really *do* use the service system. The usage of the service is part of the service concept, enabled by a good technical architecture, and offered by a good organizational architecture. However, it is good to realize that the usage of a mobile service system implies costs and benefits, as presented in the previous subsection.

We argue that it is important to design the service system in a way that clearly defines the components that will be used to create value using the mobility solution because the mobility solutions that can be offered are tightly linked to business processes, thereby making it difficult to design the operational processes. However, this adds importance to the quality of service aspect, especially as it is related to the outcomes of using the service.

The best known service quality dimensions are proposed, and improved in later versions, in the SERVQUAL model by Parasuraman et al. (1991): reliability, responsiveness, tangibility, assurance and empathy. Kaymana and Black (2000) and Liljander et al (2002) published quality dimensions of e-services based on the dimensions of the SERVQUAL model. Since mobile workforce solutions are a kind of e-service, these dimensions are reviewed and applied to mobile service design based on the work of van de Kar (2005) in the following way.

- Reliability. This is very relevant for mobile workforces considering the fact that users of the mobile services are on the move and often in time-critical situations.
- Responsiveness. The time-critical situations of the mobile workforce environment enforce this service quality dimension.
- User Interface. The small screen of mobile devices that are easy to carry and convenient to use by the mobile workforces demand special requirements of the user interface.
- Trust. The mobile workforces should have a feeling of confidence and trust regarding privacy and security and freedom of risk when using information provided to them via the mobile solution.
- Customization. Mobile users personalize the screen, tunes and navigation menus of the mobile phone. The same case applies to mobile workforces, and they should be provided with means to customize their devices.

To achieve quality of the mobile service parameters effectively, there is need to conduct studies among mobile workforces to confirm the usability of the mobility solution and the value it adds to a business process.

4.4.6 Develop, deploy and evaluate the mobile solution

As stated at the beginning of this section, the activities in this phase are not the focus of the recipes in this research, and we will therefore not discuss them in detail. In this phase, it is worthwhile to remember that mobility is simply an enabler to a business problem, and not a goal in itself. Mobility is just an extension of current enterprise architecture and should be treated as such when developing mobile workforce solutions. Developing a mobile solution is a complex task that cannot be accomplished without applying the usual rigorous software development standards. We argue that it is necessary to develop mobile workforce solutions that accommodate rapid introduction of new services. However, this means that we also have to be careful about security and trust related issues.

Horizontal versus vertical applications
Depending on the type of organization and business process to be enabled by the mobile solution, we recommend the use of either vertical or horizontal applications. Horizontal applications are generic applications like email and inter/intranet access. In most cases it is difficult to build a solid business case for developing these applications as part of a BEaMS project. However, they do improve efficiency and remote work possibilities for employees. An advantage for implementing a horizontal application is that it provides a way to gain experience in mobility.

Vertical applications are business specific applications that enhance functionality or efficiency by adding a mobility component. In most cases these applications have to do with the core processes within a company. In such vertical applications, it is important to deploy simple client software that supports field workers e.g. sales people, field service personnel, chauffeurs, and pharmaceutical representatives, who need very simple client applications that boost utility by limiting options instead of expanding them.

Extensibility and standards compliance are paramount
IT systems developed or purchased to support mobility must be extendable, able to cope with change and compliance to standards compliant. This ensures that the organization does not have to keep developing or maintaining proprietary solutions. Systems adopted for the mobile workforce solution should be based on widely accepted standards.

Deploy proven solutions that are secure and easy to use
Whatever solutions are adopted to fulfill the technical part of transformation to the mobile solution have to be secure, easy to use, and preferably proven in the field. The more common the technologies used are, the easier it is to convince an organization to embrace them since the perceived risk stemming from their usage is reduced and their effectiveness largely proven (Kornak et al., 2004). For instance, a simple email to an SMS gateway system would boost the adoptability by the mobile workforce significantly, allowing for faster, reasonably priced communication. On the other hand, offering the mobile workforce a state of the art PDA to use over GPRS to access their company's systems might prove an error prone, complex exercise with a lot of associated cost.

Consider trust issues during evaluation
The issue of trust is very much brought to the forefront in mobile workforces and this means that organizations must ensure that employees know what is expected of them in terms of productivity, behavior and reporting. This is especially the case in situations in which decision makers expect to

see increased individual productivity levels as a direct result of deploying mobile solutions. This implies that steps need to be taken to ensure that the guidelines and policies are understood and adhered by the organization, and that appropriate back-up, support and training are provided for the mobile workforce.

4.5 Requirements for the suite

As we have discussed in chapter 3, section 3.4, s*uites* are integrated IT development tools, systems and analytic methods that focus explicitly on enhancing the studio decision process. Many kinds of suites are needed to support the full implementation of the recipes we proposed in the previous section. For example, IDEF tools, CASE tools, ARIS tools, and project management tools (e.g. PERT chart) are all available technology suites that may be used for the different activities of a BEaMS project that were discussed in the recipes. However, we argue that there is the lack of a dynamic modeling support suite that is aimed at supporting process analysis and the mobile solution design activities that we specified in subsection 4.4.5. In this section, we discuss the reasons for developing a simulation suite, with a focus on the functionality of the suite. We present the process of developing the suite in the next chapter.

4.5.1 Reasons for developing a simulation suite

The reasons for developing a suite within the support studio are in line with the studio design requirement 4, and are mainly based on the lessons learned from the two inductive cases presented in chapter two. The lessons learnt regarding the process analysis aspect can be re summarized as follows.

- The desired improvement of field operation efficiency and effectiveness is poorly analyzed using quantitative measurement at the beginning of the project. This in turn causes difficulty in evaluating the business gains of the project.
- There is almost no what if model on the situational changes caused by deploying mobile workforce solutions. This makes it impossible for management to be proactive to potential consequences, such as dynamic dispatching, instead of traditional batch-based dispatching.
- There is no effective support for business analysts and service designers to asses the influences of different technical solutions jointly on business processes and operation performance.

These lessons are considered to be challenges to the effective design of mobile workforce solutions. In order to tackle these challenges, we have provided the recipe in subsection 4.4.5 for analysis and design activities of a BEaMS project, emphasizing a focus on process modeling and redesign. We argue that a suite is required to enable the implementation of business process modeling. We will explain further why simulation was chosen to fulfill the requirements of the suite, i.e. the suitability of simulation for business process modeling. There are several characteristics of simulation that make it suitable for business process modeling, and especially in the domain of BEaMS projects.

Quantitative analysis

Simulation models can provide quantitative information that can be used for decision-making. As was discussed in section 3.3.3, simulation fundamentally enhances process performance analysis by introducing dynamic parameters of the process. For example, a process-based world view in simulation modeling terminology relates to a time-ordered sequence of interrelated events which describe the entire experience of an entity as it flows through a system which is comparable to the flow of entities through business processes (Hlupic & de Vreede, 2005). The flow of information within and between business processes can be modeled as the flow of temporary entities between processing stations. Observations from the case study presented in section 2.4 revealed that mobile workforce solutions have direct impacts on many other work-related aspects, and it is necessary to perform an analysis of these impacts in a quantitative manner.

Modeling dynamics
Simulation methodology was chosen, because currently existing problems in mobility related processes have been clearly related to dynamic parameters, such as time, volumes, capacities and quality. Arguments for the use of simulation as a method for handling the dynamic modeling of the business processes was presented in section 2.4 and in section 3.3.3. Simulation has been identified as an extremely useful tool for solving such problems (Giaglis, Paul, & Doukidis, 1996; Swami, 1995; Tumay, 1996). Simulation can enable the migration from a static towards a dynamic process model. It has been used to provide insight into dynamic features of current and future process design, which could not have been obtained with traditional, static modeling tools.

Experimenting alternatives
Furthermore, simulation models can capture the behavior of human and technical resources in the system. In section 2.4, we presented the view that organizations should be provided with a chance to determine the effects of making a given change in their business processes. This view supports the use of simulation models to perform 'what-if' analysis. A simulation model can be easily modified to follow changes in the real system and as such can be used as a decision support tool for continuous process improvement (Aguilar et al., 1999). Statistical representation of real-world uncertainties is an integral part of simulation models (Giaglis et al., 1996). Discrete-event simulation models can be used to 'mimic' the stochastic and unpredictable behavior of process redesign (Hlupic & Robinson, 1998).

In conclusion, grounded on the problems of current analysis and design practices observed in BEaMS projects, we see there is a need to improve the process modeling approach with support from a simulation suite. Using a suite should help decision makers to address process related design issues of mobile workforce solutions, such as workforce utilization, process optimization, scheduling and dispatching capacity, and scenario experiment.

4.5.2 Functionality of the simulation suite

It is important to note the differences between a simulation model and a simulation suite. According to Keen and Sol (2007), a suite is a set of components to support a decision making process, and is basically a combination of information technology tools and the development methods used to apply them. A simulation suite is used to construct simulation models for a particular use; and simulation models are one kind of output of a simulation suite.

It is also clear that the simulation suite to support BEaMS is not intended for algorithm optimization, e.g. to determine the optimized number of mobile workers needed to achieve a specified response time, a traditional use for a simulation model. We follow Keen and Sol (2007), who state that a suite should provide more functionality and serve as a kind of "diagnosis tool", allowing the users to "tune" it to meet their needs. Based on the previous discussion on characteristics of simulation in process analysis and design, we specify the following functional requirements for the suite.

Modeling dynamics: A simple model can be used to understand whether the new process or processes are feasible. A simulation model with the appropriate level of detail can be used to understand process performance under specific "special" or "common" causes of variation.

- *Req.4-1.* The suite should support the demonstration of key changes due to the proposed mobile solutions on business processes.

Quantitative analysis: Once a simulation model is built, further detailed analysis can reveal specific performance characteristics of the redesigned processes, such as "time to satisfy customer" or "customer waiting time". These metrics can be compared with the current state or best practices metrics as a benchmark.

- *Req.4-2.* The suite should support quantitative analysis of key system performance indicators through statistical features.

Experimenting alternatives: The animation feature of the simulation models can enhance the communication capability. Simulation thus provides decision makers with a means to evaluate the trade-offs of various scenarios, prioritize influencing variables and test their impact on the business system.

- *Req.4-3.* The suite should support the evaluation of results of different experiment results through an animation feature.

We argue that these functional requirements have to be met by the suite. It should also be noted that, there are also non-functional requirements that must be set to steer the usability of the suite. We will elaborate on these non-functional requirements in the next chapter.

In conclusion, the simulation suite should allow service designers to simulate and evaluate business processes and design scenarios. It should also allow mobile workforce parameters to be adjusted easily to reflect the way a business wants to shape its operation, thereby enabling mobile services to help change its business processes. We will discuss how the simulation suite is brought to the reality, and narrow down our focus to the field service industry. We develop a domain specific simulation suite for this particular industry in chapter 5.

4.6 Reflections

We started this chapter with a discussion on the essential requirements of a support studio for BEaMS. Based on the case study material presented in chapter two, we formulated four requirements for each of the components of the studio: landscaping and initiating guidelines, operational recipes, and a supporting simulation suite. Each of these components of the support studio reinforces one of the "ways of" framework taken from Sol (1992). We look back at the support studio developed and provide a reflection on the chapter based on the requirements for the studio that were presented in section 4.1.

Reflections on requirement 1: this requirement stresses that the studio should provide guidelines that enable decision makers to increase awareness of mobile workforce solutions on organizations, and trigger a proactive approach for BEaMS. This is about forming a starting point among the decision makers, explaining what and why of mobile services, and reinforcing a way of thinking in the BEaMS project. We presented a set of guidelines that enable the decision makers to create a systems thinking and conduct the BEaMS project using a business process engineering approach.

For example, we proposed to use the concept of a mobile service system to achieve the system view to support the fulfillment of this requirement. According to Checkland (1999), systems must be developed for the organization as a whole rather than for functions in isolation. We adapted this view from Checkland (1999) and argued that the design of mobile workforce solutions should not be done in isolation of the rest of the organization. In principle, hard systems thinking and soft systems thinking should be applied to look at an organization before the introduction of a mobile workforce solution. Systems views can be used in tackling ill-structured problems such as designing mobile workforce solutions. Optner (1965) states that the systems view enables problem solving to concentrate on the process by which things are done, rather than on final outcomes since this enables us to get a greater insight to generalize on business phenomena.

Reflections on requirement 2: this requirement stresses the need for the support studio to facilitate effective communication between stakeholders involved in the BEaMS project. The requirement enables the decision makers to enforce a way of controlling for the project team. We proposed that to facilitate the decision makers we need to regard the changing roles and capabilities of the various types of mobile solutions providers as an important issue, because it helps to clarify roles and actors of a BEaMS project. We argued in favor of consultancy in designing the mobile solution, which further strengthens our argument that there is a need to involve people from different organizations, e.g. business analysts, service designers, operational managers, mobile workers, project leaders, etc., for a mobile service development or BEaMS project.

Reflections on requirement 3: this requirement stresses on enabling service designers to focus their attention on relevant issues during the design of a mobile solution. The requirement enforces a way of working at the operational level of the BEaMS project. To address the requirement we stated that the support studio should provide precise guidelines on what needs to be done in a BEaMS project but leaves open options for variations in detail. Towards this end, we presented the recipes for use within the studio. The recipes provide the sequence of steps to be followed to achieve a BEaMS effort. The recipes center on the design of mobile workforce solutions in a multi-actor situation, with the aim of supporting each of the actors in performing their mobile service design activities.

Reflections on requirement 4: this requirement stresses the need to capture effective "as-is" models of the business processes targeted by the BEaMS project, and to support the decision makers in performing "what-if" analysis of the proposed mobile solution. To address the requirement, we proposed the use of a simulation suite and discussed the underlying reasons in support of the simulation suite. The functional requirements for the simulation suite were formulated in subsection 4.5.2., which can be regarded as sub requirements of the requirement 4. The development of the suite is discussed in the next chapter.

Overall, we argued for the need to provide tools that can support decision makers in the design of business processes supported by mobile solutions, and proposed the use of dynamic modeling approaches. To provide this support, we considered the use of a simulation suite for deployment within the studio as the best way for modeling the dynamics inherent in a mobile workforce business process. We also argue that following the recipes presented in this chapter will lead to more effective design of mobile solutions. Generally, we reflect that application of the support studio will result in the development of robust and reusable business processes for the mobile workforces. The constructs of the studio and the supporting discussions presented in this chapter form the basis of our theory, which we shall expound on further in the next chapters. We will focus more on the simulation suite and its application in supporting the analysis phase of the BEaMS project.

Chapter 5 A Suite for Mobile Field Services Modeling and Simulation

The aim of the suite is to support the modeling of business processes of mobile workforces by providing generic building blocks, which can be assembled and customized to analyze targeted business processes. To pursue the research objective, we first introduce the development of the suite by discussing the concept of simulation building blocks in section 5.1, in which we also discuss how we derived a basis for identification of the building blocks implemented in the suite. In section 5.2, we present a specification of the simulation building blocks, followed by a description of the implementation considerations. We illustrate the functionality of the simulation suite in section 5.3 using two cases, and finally make a reflection on the suite in relation to how it fulfils the function requirements that were presented in chapter 4, sub section 4.5.2.

5.1 Conceptualization of the building blocks for the suite

5.1.1 Use of building blocks and service oriented architecture

As we explained in chapter 4, suites are used to provide the technology to support recipe application. The research objective was to develop a simulation suite to support process modeling activities in the analysis and design phase of a BEaMS effort.

Following on Janssen and Sol (2000), we proposed the use of building blocks to avoid a time consuming process where simulation models for BEaMS would have to be developed from scratch each time they were required. We expect that the provision of building blocks eases the construction of simulation models for field service processes enhanced by mobile solutions. The use of building blocks makes the development of models faster, experiments are better focused and evaluation of the outcome is easier (Verbraeck & Valentin, 2001).

The generic building blocks must be able to model most of the mobile workforce-related concerns, such as location tracking and real-time dispatch of mobile workers, allowing the process and service designers to concentrate on process analysis and service assessment. Valentin and Verbraeck (2002) propose a framework for developing discrete event simulation-based building blocks. We use this framework to structure the steps to develop the building blocks.

In the first phase we study the targeted application domain and discuss some of the problems worth modeling; the second phase is used to perform an object oriented analysis, and the outcome is turned into the model building blocks in the third phase (see 5.1.2 and 5.1.3). In the final phase the model building blocks are implemented in a simulation environment (see 5.3).

Developing building blocks that have different functionalities is not the only ultimate goal. Building blocks must be developed in such a way that they can interface appropriately with each other and can be composed to provide certain services as a suite. To put this into practice, we choose service oriented architecture (SOA) as an important principle in the implementation phase.

SOA is an approach to software design ("architecture") where applications are assembled from reusable components ("services"). It is an architectural approach that makes it not only feasible, but practical, to build business applications through a collection of loosely coupled services (Kelly, 2005). A service is a software building block that performs a distinct function, such as retrieving customer information from a database, through a well-defined interface.

Using SOA, the software is organized into loosely coupled modular components. Loose coupling is significant because it underlies the flexibility behind SOA, and it basically means that services can be linked together dynamically at run-time, with few dependencies on how the services are actually implemented. The majority of the benefits of SOA are realized when existing services are assembled into composite services. Service composition allows us to create solutions on top of existing services (Manolescu & Lublinsky, 2004).

The development of services based on the concept of SOA is becoming the prevailing style for development of services. With this concept, any functionality can be made into a service. The thinking behind the SOA concept is considered to be important, and it is therefore adopted in architecting the suite. The simulation suite developed in this research can therefore be seen as a set of software building blocks that provide services, with well defined service interfaces that are at the right level of abstraction.

5.1.2 Choice of object-oriented analysis

Object-oriented techniques have become popular because they are especially suitable for modeling complex, large-scale systems consisting of multiple active entities, a description that fits many business processes (Nidumolu, Menon, & Zeigler, 1998). In particular, some of the advantages of using object-oriented techniques for business process modeling identified by Jacobson, et al. (1995) are:

- comprehensiveness: the overall business and its components can be modeled using classes that can be ordered hierarchically, thus allowing complex models to be constructed or decomposed.
- understandability: real world objects can be mapped directly to objects in the business model.
- changeability: encapsulation allows changes to the implementation of an object's operations without affecting other objects, as long as the interface remains the same.
- adaptability: class inheritance allows specialization of the process model to different situations.
- reusability: because objects are relatively self-contained in terms of operations and attribute, they can be reused in other process models.

While there appears to be general consensus among IS researchers that object-oriented techniques offer considerable potential for business process modeling and simulation, there is little agreement on the specific approaches to pursue (Nidumolu et al., 1998). A variety of object oriented modeling and simulation approaches are evaluated by Nidumolu et al. (1998), as described below.

- Petri-net based approaches: these approaches attempt to model interactions between objects as a Petri net. These approaches are good for modeling systems with many intermediate states and at representing concurrency and synchronization. However, the basic constructs in Petri nets are non-intuitive and difficult to map from the business processes being modeled, and the models quickly become large and difficult to comprehend even for small increases in process complexity.
- Role-based approaches: these approaches model objects in a business process primarily in terms of the different roles that they play, and the interactions between these roles. These approaches are good at model representation because roles have a natural mapping to the activities of individuals in organizations. However, model manipulation and implementation are limited.

- Information systems architecture-based (ISA) approaches: these approaches seek to model the business processes as well as the information resources in an organization, and also identify the interrelationships between them. These approaches have powerful capabilities for model representation which incorporate different views of layers of the business organization. However, they tend to be relatively static representations of the business process, with little support for dynamic modeling capabilities beyond the description of interaction between objects.
- Discrete event simulation-based approaches: Discrete event simulation models are especially powerful in modeling business processes because of their ability to represent process flows where entities such as customer, products, documents and other objects arrive and leave processors at discrete time intervals. Discrete event simulation based approaches such as "dynamic modeling" (Sol, 1992) are rich in providing constructs for model representation and in descriptions of "real world" business implementations.

For the purpose of identification of the simulation building blocks in this research, we prefer to use discrete event simulation-based approaches. In particular, we prefer to use a dynamic modeling approach because the focus of this research is less on process modeling tool development, but more on the use of process modeling in organizational settings. A strong feature of the dynamic modeling approach is its rich description of a methodology for model implementation for a variety of business contexts. It has been used successfully to model business processes in government organizations (Dur, 1992), logistic companies (Janssen, 2001), police department (van Meel, 1994), criminal investigation departments and software-supported groups (de Vreede, 1995)

Further, we chose to use Unified Modeling Language (UML) for the purpose of designing the library of building blocks based on object oriented design. UML is an object oriented modeling language for specifying, visualizing, constructing, and documenting the artifacts of software systems, as well as for business modeling and other non-software systems (Rumbaugh, Jacobson, & Booch, 1998). In particular, we use UML *Class Diagram* and *UML Sequence Diagram* in this study for conceptual design of the building blocks and conceptual modeling of the relevant business processes. The class diagram is used to provide a *structural view* of the system in terms of objects and their relationship. The sequence diagram is used to provide a *process view* of the processes and objects that perform the processes.

5.1.3 Characteristics of the application domain

With the development of mobile technologies, from smart phone to virtual machine, the field service industry is faced with many opportunities to change the traditional operations. For example, Pavan (2004) proposes a mobile solution that aggregates equipment information at a territory level and assigns technicians to the model rather than assign technicians to each unit of the equipment. Pavan (2004) claims that the solution enables faster assignment and helps restocking analysis programs to identify accurately which and how many of each part a technician needs to carry. We contextualize the discussion using the domain of field service organizations.

5.1.3.1 Field service organizations

Field service organizations support the customers' use of the tangible, core products, for example, the installation, repair and maintenance of a variety of equipment (Klimberg & van Bennekom, 1997), or of the intangible services including police and courier services From a systems view, field service oriented organizations are organized around a value system that is focused primarily on customer satisfaction. How to achieve effective response-time planning is a major concern from an administrative perspective. Conventionally, significant operations research has been conducted to cope with these challenges, such as in the area of facility location models (e.g. (Hill, March, Nachtsheim, & Shanker, 1992)).

The response-time planning problem is challenging primarily because it involves queuing. Some research has therefore been carried out based on the queuing nature of the field service system. Field service systems are often modeled as queuing systems: service calls contend for one or more service engineers, which can be regarded as a single queue with multiple servers. Hambleton (1982) describes a square root model for the multiple server, sequential trip, and infinite calling population field service system. Hambleton (1982) points out that since the service rate was partly dependent on the travel time as determined by the number of technicians, the normal "queuing theory" models could not be applied. Watson et al. (1998) state that when the nature of a queuing problem defeats analytical solution, one may turn to analyzing dispatching strategies by simulation in an attempt to learn how best to deal with the problem. The dispatching problem is concerned with deciding the order in which incoming calls for service are taken, and which customer service engineer should respond to each call.

Although this research does not fall into the operations research category, our interest is to improve business processes of field service organizations through the use of mobile solutions, and ultimately to design mobile workforce solutions that support the work of the field workers. We elaborate this further by looking at field service processes next.

5.1.3.2 Field service process

A typical field service process can be explained in general as follows. A customer places a service call; the dispatcher dispatches a technician to the customer location; the technician resolves the customer's request. These processes are shown in figure 5.1.

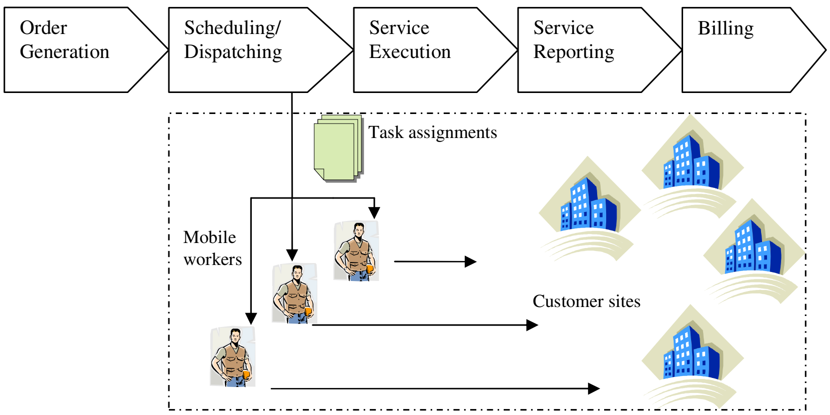

Figure 5. 1 General field service processes

From this basic but typical explanation, we observe that there are several logistics issues that need to be taken care of to make the process work effectively. For example, we are in agreement with the work of (Pavan, 2004) which identifies the following examples of issues that need to make the process work effectively:

- the speed with which the technician is sent to the customer location

- assigning a technician with the right skills set for the job
- the technician processing the correct spare parts that are required to repair the machine on his first visit to the client site, called the first-call effectiveness.

5.1.3.3 Key performance indicators of field service process

We observe that field service processes require management of the operations, which in turn cause planning problems. A major planning problem for most field service operations concerns the staffing cost and customer satisfaction. Field service management seeks to balance costs against customer satisfaction, which is usually measured in terms of responsiveness.

Response time

Following on (Haugen & Hill, 1999), we learn that response time historically has been the dominant performance measure for field service management. Customers measure the quality of the service received based upon the time to resolve the problem, and more importantly upon the speed of response. The response time requirement typically ranges from one hour to one business day, depending on the customer service demand being handled. Priority classes of customer demand exist, which depend upon the criticality of the customer application; the most common cases are concerned with an environment of uniform response requirements, and because customers use response time to assess service quality, many field service organizations have a policy goal of responding quickly.

Workforce utilization

In addition to the objective of minimizing the required response times, the management of field services also has an objective to optimize the workforce utilization. That is why traditionally field services are planned in the aggregate for the number and location of field offices and the number and skill level of the field engineers to be housed in each office. The complexities and uncertainties of the operating environment present many challenges for traditional aggregating planning (Pavan, 2004). The total field engineer labor hours needed is a function of multiple variables: characteristics of equipment; characteristics of the field engineers; the required response; field office locations; and customer locations.

5.1.3.4 Changes enabled by mobile solutions

The introduction of mobile solutions has enabled several changes in the work performance of mobile workforces. Traditionally, the field service personnel required frequent phone interactions with the dispatch centers before, during, and after service work orders to clarify requirements, report status, or check on spare-parts inventory, etc. Similarly, if a dispatcher or coordinator wanted to check a field worker's availability or location, they had to call the field worker through their mobile devices or send a message to their mobile devices by SMS. Currently, with the high speed network (e.g. GPRS) and the GPS system, a PDA based solution, for example, can enable information (e.g. on the location) of a mobile worker to be easily available all the time through a kind of "dashboard". The major opportunities provided by such kind of mobile solutions, and the changes enabled by this kind of solution can be grouped into four categories, as identified by (Vigoroso & Gecker, 2005).

Mobile scheduling/dispatching

Mobile solutions provide the critical link to the field for schedule and route optimization solutions. Using the mobile solutions it is possible to improve first time resolution rates, increase worker productivity and lower administrative overhead by improving and automating the scheduling and dispatching of mobile workers. Foundational requirements for mobile workforce scheduling and dispatch include visibility into workers' locations and availability, current profiles of worker skill sets, and accurate calculations of "wrench time" i.e. time spent working, and "windshield time" i.e.

time spent on traveling. Mobile field service solutions also enable the automatic scheduling of routine work orders as they come in using a set of preconfigured rules.

Advanced mobile workforce solutions utilize devices equipped with global positioning satellite (GPS) or geographic information system (GIS) functionality and integrate with mapping software to allow for visibility into the workers' locations. This location-based data serves as critical input for optimization solutions that calculate lowest-cost, highest-throughput routing schemes, and also allows dispatchers to make adjustments to service schedules and manage customer expectations as necessary.

Mobile work order management

Service work order management encompasses all the activities related to receiving, accepting, and transacting work orders in the field. These activities include accessing customer requirements and history, logging service order and customer status data, billing and invoicing information, and workflow escalation requests. Mobile workers and back office personnel also need to effectively track labor, materials, and time spent at each job site for improved performance monitoring.

Solutions addressing mobile work order management aim to minimize manual and redundant data entry and improve data accuracy. Effectively tethering mobile workforces to back office systems, mobile work order management streamlines the administration of service accounts, speeds up the order-to-cash cycles, and can moderately increase worker productivity by allowing mobile workers to complete more work orders per day.

Mobile inventory management

For mobile workforces that maintain service parts inventory in their vehicles, mobile inventory management functionality is key to helping the workers to monitor parts usage, adjust stock counts, and restock vehicles efficiently and accurately. Mobile inventory management solutions enable the tracking of parts used on the job site and report this information to the back office for part replenishment and stocking level adjustments at central, field, and truck stocking locations.

The mobile inventory management solutions can enable mobile workers to enter part numbers into the system or integrate with bar-code scanners on the device for faster and more accurate data capture. By increasing visibility into the flow of parts among central, field and truck stocking locations, enterprises can better control stocking levels, reduce shrinkage rates, and streamline the transfer of parts from the warehouse to the field.

Mobile asset management

To complete complex installation, repair, or reconfiguration tasks effectively, mobile workers may need access to electronic catalogues, maintenance and repair bulletins, asset performance history, best practice scenario resolution, and other work-related information. Mobile asset management functionality allows the mobile workers in capital-intensive industries to access, capture, and transmit critical data from equipment inspections and service. In many cases, this data takes the form of three-dimensional diagrams, photographs, and video.

In addition, mobile asset management functionality allows mobile workers to track and monitor asset health histories to ensure optimum uptime and performance. Advanced solutions enable mobile workers to perform measurements and meter readings with scanners housed in handheld devices.

Reflected on the potential applications of different mobile solutions in the field service industry, we summarized the following issues that may be interesting to simulate to support managerial decision making and the design of new business processes enabled by mobile solutions.

- *Real time information updating:* with the registration of time and location of field workers enabled by mobile solutions, service managers are able to receive information regarding events in the field. They can obtain up-to-date information regarding if a mobile worker is on-site, if a job is running over its scheduled time, if the job is done early and the worker has more capacity, etc. The use of a mobile solution can also make asset, customer, and work-order data available to field workers via mobile devices.
- *Dynamic dispatching*: with real time connection enabled by the use of a mobile solution, dispatchers can assess a worker's workload at a glance. The information obtained allows the dispatcher to assign workers and to do it based on the "work-load" of the worker. The dispatchers can mix-and-match to distribute the work load uniformly among all the mobile workers thereby enabling ongoing optimization throughout the day, as mobile workers can be easily reassigned or rerouted at any time of the day.
- *New ways of working:* the addition of mobility to scheduling has enabled the introduction of new ways of working, and thereby brought the opportunity for mobile workforce management. For example, the "drip-feed" approach to scheduling, in which a mobile worker is assigned one or two jobs at a time throughout the day, as opposed to being assigned all of the day's jobs up front may provide higher levels of resource utilization.

Based on the preceding discussion, we conclude that mobile workforce solutions open up a world of opportunities that require service designers to be provided with tools that enable them to leverage the practical knowledge and ability to design mobile workforce solutions. An example is the case in which the mobile workforce solution is integrated with service optimization technology. This would enable the service designers to use their knowledge and experience to help organizations to move beyond the basics of using location technology, to employing the information received from the location technology in new, more actionable ways. When the mobile workforce solution is combined with dynamic dispatching, the service designers can for example, demonstrate how location based services (LBS) can help in the mobile worker dispatching process, enabling them to anticipate delays, prevent late arrivals, and minimize unnecessary travel.

We used the preceding discussions to identify the problems in the domain area, on which to base the conceptual design of the simulation building blocks.

5.1.4 Conceptualization of the building blocks

Targeted problems and boundary

The main issues arising from analysis of the business processes in the mobile field service domain are considered to be typical of some of the processes encountered in a BEaMS project. Through the study of field service process (see 5.1.3.2) and the changes enabled by mobile services (see 5.1.3.3), we gathered general information on the 'as-is' field service processes and were able to identify the relevant issues to be considered in designing the 'to-be' field service processes. We found out that dispatching and resource allocation are activities that occur in almost all domains that utilize mobile workforces, and that these activities could be done better if the processes were supported by mobile service solutions. It is desirable for decision makers to be able to see in advance the effects of changes to be made in dispatch and allocation processes with the introduction of mobile solutions. We therefore focused the design of the building blocks on simulating new dispatching and resource allocation processes enabled by mobile services, as activities that are generic for mobile workforces.

The most common problems perceived from the literature and actual practice can be summarized as the difficulty of performing "what-if" analysis of the real time dispatching and resource allocation processes enabled by mobile services, such as the location based services (also see section 4.1). In particular, we limit the scope of the building bocks to providing support for the following issues in the field service domain.

- The decision makers currently lack insight into the dynamic dispatching and resource allocation mechanisms enabled by mobile services.
- The decision makers question the efficiency gains from the provision of mobile services in terms of minimization of response time to an order, and the maximization of their field workers' utilization if a new dispatching policy is to be implemented.

We argue that the building blocks should have the potential to support the performance of functionalities required for handling, and to provide answers to, the issues identified above. We argue that this consideration is in line with the functional requirements of the suite (i.e. Req. 4-1, 4-2, and 4-3) that were identified in chapter 4, section 4.5.

Method and result

In line with our argument in 5.1.2, we preferred to use object orientation to conceptualize the design of the building blocks. We generated the initial object models of the field service processes based on the information identified through literature and best practices as discussed in the previous section. We present the initial object model in figure 5.2.

The basic idea is that a field service process begins when a customer order is received at the customer centre, and we therefore conceptualized building blocks to model this process. Considering that the orders are generated by customers, we felt that it was logical to have a building block that can be used to model the customer and the kind of service order they give. We also considered the fact that customers were spread over different locations, all with different roads that may be used to get to the locations, and came up with building blocks that can be used to model customer locations and roads to get to the locations. It is also necessary to model the activities of the mobile workers, and we therefore identified a building block for the mobile workers. More importantly, in developing effective mobile workforce solutions, there is a need to have a dispatching policy that can be used by the dispatch centre to send the mobile workers to the appropriate customer location, and also to schedule the regular mobile worker tasks. This led us to develop separate building blocks that would be used to model the dispatching policy.

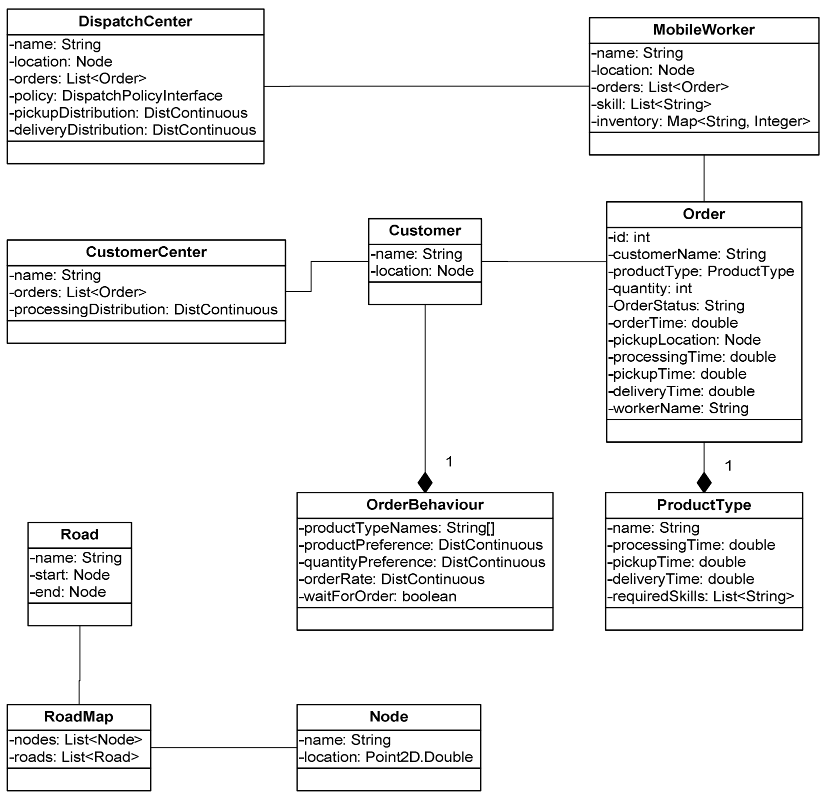

Figure 5. 2 Initial object models of field service processes

Based on the initial object models, presented in figure 5.2, we elaborate further the design of the building blocks next. We emphasize that the building blocks for the simulation suite should consist of pre-defined behavior that represents the various business processes identified through literature and best practices. Moreover, characteristics of the building blocks, such as quality, speed, maintainability and extendibility, generality, and reusability (see section 5.1) should also be considered. For example, there is a need to balance the trade-off between the information content of the building blocks and the size of building blocks, i.e. the more information added to building block, the bigger the building block and the less reusable it might be. A detailed explanation of the functionality of each of the building blocks is given below.

- Customer
- DispatchCenter
- Order
- RoadMap
- CustomerCenter
- MobileWorker

Customer
This building block represents customers, who generate orders and send them to the customer center. The *Customer* building blocks receive services from *MobileWorker* based on previously raised orders.

DispatchCenter
The *DispatchCenter* building block monitors field workers' task conditions, and matches the orders with the right field workers. The building block is also responsible for choosing appropriate dispatch policies, based on which it determines the orders to be assigned. The input of this building block includes all types of service orders, and field worker status such as availability and current location. The input information comes from other building blocks. For example, it receives service orders from *CustomerCenter*, and location information from each *MobileWorker*. The output of this building block is mainly a schedule for each field worker.

CustomerCenter
The *CustomerCenter* building block simulates the role of customer center in reality. It performs the functions of checking validity of orders (e.g. checking the availability of the ordered products with the inventory system), grouping orders (e.g. based on service level agreement), and documenting orders in administration system. Though some functions played by *CustomerCenter* in reality can just be abstracted as a time delay for simulation purposes, we still make it as a separate building block because in some complex business situations, it is also important to simulate the logic of those functions. The inputs to this building block are the orders generated by *Customer* building block; the outputs are the sorted orders for the *DispatchCenter* building block.

MobileWorker
The *MobileWorker* building block simulates a worker's activities in the field such as performing tasks at customer site, responding to assignments from dispatch center, traveling between various locations and taking breaks. Workers perform field service based on schedules generated by *DispatchCenter*. After an assignment is completed, the service information should be able to be passed to *DispatchCenter* building block to update the corresponding dispatching conditions.

Order
The *Order* building block simulates an actual order from a customer. The *Customer* generates an *Order* that is sent to the *CustomerCenter,* which in its turn sends the order to the *DispatchCenter*. With a certain dispatching decision, the order is processes by an allocated *MobileWorker* who has the matched resources. Thus the order has also a functionality to represent the task for the *MobileWorkers*. Each order has an *OrderType* which specifies all detailed content.

RoadMap
The *RoadMap* building block represents a map in reality, and contains a set of nodes and a list of streets. The functionality of this building block is to provide route information which a mobile worker may follow to arrive at a certain location.

In the next section, we present further discussion on the specification and implementation of the simulation building blocks with a focus on BEaMS.

5.2 Development of the suite

We applied a two step process to develop the building blocks of the simulation suite, namely specification and implementation. In the context of this research, specification was performed to simplify the generation of objects and attributes to be implemented in the building blocks. The integration of the building blocks into a BEaMS simulation environment is carried out in the implementation step.

5.2.1 Specification of variables

The exogenous inputs, experiment variables, and performance measures that needed to be specified are outlined in figure 5.3, and are explained after the diagram. These variables were identified, formulated and specified based on literature, empirical data, and assumptions made in this research.

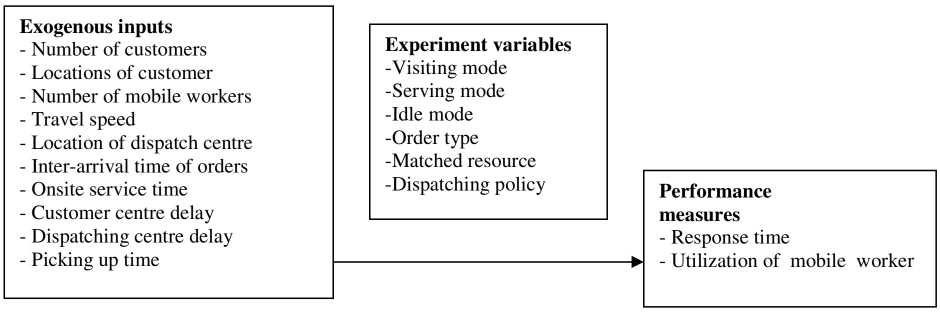

Figure 5. 3 Overview of variables for specification

Exogenous inputs

The number of mobile workers, the number of customers, the locations of customers, and the location of the dispatch centre all need to be specified to initiate a simulation model. The value of these inputs can be obtained depending on the case selected.

According to Watson (1998), if the purpose of a study is to examine a specific field service process, clearly, any travel speed, inter-arrival time of orders, and onsite service time distribution may be assumed. The effort to specify, as discussed here, is for the purpose of outlining a format for reference. Given that a simulation model has many input parameters, we considered it is best to maximize the regression fit with a minimum number of parameters when specifying the exogenous inputs of the simulation suite.

It is worth mentioning that the activity durations of discrete simulation models are often stochastic. That is, they vary in some manner which can be described by a probability distribution. For example, the pick up time for a product at an inventory may vary from occasion to occasion even if conditions remain more or less the same. These variable durations are usually simulated by taking samples from probability distributions using various types of sampling methods. (Detailed methods can be found (Pidd, 2004)). For such exogenous variables, we chose probability distributions as default values that matched real systems modeled in earlier papers, e.g. (Haugen & Hill, 1999; Klimberg & van Bennekom, 1997; Watson et al., 1998). We give some examples below.

Travel speed

Given the purpose of applying simulation in BEaMS projects, we think that the acceleration and deceleration of mobile workers are over specified and therefore it is not necessary to model them. In the simplest situation, the travel speed of a mobile worker with a vehicle can be estimated as a constant value, such as 30 kilometers per hour within cities. Nevertheless, it may also be possible to model it as a function of a number of factors, such as the geographic characteristics of the order, and the road type the mobile worker needs to travel. Thus a certain speed distribution, such as a Triangular distribution may also be used to specify a travel speed (Haugen & Hill, 1999).

Onsite service time
We assume that the onsite service times are independent and identically distributed. The onsite service time can be well represented by the Gamma distribution with a shape parameter equal to 2 (Watson 1998). Since it was reasonable to assume a maximum service time, the Gamma distribution is truncated to avoid excessively large service time values. Haugen and Hill (1999) suggest that the *onsite service time* can also be modeled with an Exponential distribution.

Inter-arrival time of orders
We assume that the inter-arrival times are independent and have a common distribution. In many practical situations orders arrive according to a Poisson stream, i.e. exponential inter-arrival times (Watson ,1998). Though in some reality, orders may arrive in batches, we consider orders arrive one by one in this study because this is the major situation in field service industry.

Input Parameter	Specification	Relevant Citations
Travel speed	Constant value or Triangle distribution	Haugen & Hill (1999)
Inter-arrival time of orders	Exponential distribution	Watson et al. (1998)
Onsite service time	Exponential or Gamma distribution	Watson et al. (1998) Haugen & Hill (1999)

Table 5. 1 Input parameters with distribution characteristic

Experiment variables

Experiment variables are used to represent various contexts in the field service domain. With different settings of these variables, the most typical business processes in this domain will be modeled and simulated. These variables are briefly discussed below. Detailed illustration of these variables can be obtained from the cases, i.e. Falk G4 and KCI presented in section 5.3.

We first look at the variables inherited from the characteristics of different field operations, namely the trip mode, serving mode and idle mode.

Trip mode
Two basic trip modes of mobile workers can be summarized in the field service industry. We use *RoundTripTravel* (Hill et al., 1992) to label the situation where mobile workers cannot be dispatched to visit the customer directly, and have to travel to a certain location before going to visit the customer. An example of such a location is an inventory. We use *SequentialTripTravel* (Hill et al., 1992) to label the situation where mobile workers can be dispatched directly to the customer site wherever they are. As we will see from the two illustration cases in section 5.3, the use of the electronic key in the G4 case is aimed at enabling *SequentialTripTravel* mode for all mobile security guards. The solution of loading spare appliances is also meant to achieve a certain *SequentialTripTravel* mode for mobile workers in the KCI case.

Serving mode
Two basic serving modes can be identified in the field service industry. We use *ProductServing* to label the situation where mobile workers serve the customer with physical product(s). For instance, in the case of KCI, the delivers serve customers with the ordered appliances. We use

NonProductServing to label the situation where mobile workers serve the customer without a bundle to physical product(s). For example, mobile security guards intervene when alarms are raised in the electronic key enabled situation in the G4 case.

Idle mode
We consider two idle modes for a mobile worker when he finishes an assignment and has no further assignments scheduled. We use *ReturnMode* to label the situation where a mobile worker returns to a certain location, e.g. office or dispatch center, to wait for next assignment. Such an idle model is applied in the KCI case.

We use *PatrolMode* to label the situation where a mobile worker moves around within a certain area, a set of customers, waiting for his next assignment. A good example of this mode can be seen in the G4 case.

Experiment variables	**Specification**
Trip mode	-RoundTripTravel -SequentialTripTravel
Serving mode	-ProductServing -NonProductServing
Idle mode	-ReturnMode -PatrolMode

Table 5. 2 Experiment variables of field operations

Secondly, we look at two variables inherited from characteristics of order and resource, i.e. products and mobile workers.

Order type
In the field service industry, it is common that customers issue orders for different products, different services and even with different priorities. It is therefore ideal to support modeling different orders, i.e. the generated order should have a basic set of attributes that can be specified for a given context. However, *priority* is not considered at this stage of the study, because we are more interested in modeling the context where the first in first out (FIFO) rule is applied to handle the orders.

We noticed that an order type is often in line with a certain serving mode. In the *ProductServing* mode, important information can be specified for an order using the *RequiredProduct*; in the *NonProductServing* mode, important information can be specified in an order using *RequiredSkill*. We discuss this further below.

Matched resource
In reality, mobile workers have different capabilities according to their experience and expertise, hence the skills levels of mobile workers differ. As we specified in *Order type*, an order may contain information regarding which required skills level is implied. Under the *NonProductServing* mode, a *Matched resource* can be specified as a mobile worker who has *QualifiedSkill* for an order. In the case of *ProductServing* mode, a *Matched resource* can be specified as a mobile worker who carries the *MatchedProduct*, note this can be seen clearly in the KCI case.

Experiment Variables	Specification
Order type	- OrderedProduct (ProductServing mode) - RequiredSkill (NonProductServing mode)
Matched resource	- MatchedProduct (ProductServing mode) - QualifiedSkill (NonProducServing mode)

Table 5. 3 Experiment variables of order and resource

Dispatching policy
The dispatching decision process has a significant impact on field service performance and is one of the best opportunities for improving response time. Hill (1992) proposed a variety of dispatching policies and compared them in a simulation experiment. Other research relevant to the field service dispatching problems is presented in Lin et al. (2002), Tommelein (1999), Boyer and Arnason (2002), Agnihothri and Mishra (2004), etc. From the literature, examples of the most commonly used dispatching policies are as follows.

- First Come, First Served (FCFS): Agnihothri and Karmarkar (1992) implied that FCFS is used in practice and asserted that the policy of guaranteed response times forces an "approximate FCFS dispatching policy".
- Nearest Call (NC): when a mobile worker becomes available, the worker is assigned to the nearest call in the queue.
- Earliest Expiration Time (EET): assign the available mobile worker the service call with earliest expiration time.
- Negative Slack-Nearest Call (NSNC): assign the mobile worker to the service call with the most negative slack. If all service calls have non-negative slack, then assign the mobile worker to the nearest call.
- Nearest Call with Positive Slack (NCPS): assign the mobile worker to the nearest call with positive slack time. If no calls have positive slack, assign the mobile worker to the nearest call.
- Composite Travel Time Expiration Time (TTET): this policy combines the objectives of the Shortest Processing Time and Earliest Expiration Time procedures. When travel times are about the same, the call with the earlier expiration time has priority. When mobile workers have high utilization, travel time has higher priority.

In reality, the real dispatching policies used are not limited to the examples above, and a mixture use or a modification of these dispatching policies are often the case. The building block should be specified in such a way that it provides the modeler with the ability and flexibility to model different dispatching policies. The ultimate aim is to support experimenting with, and obtaining feedback on the impacts of, applying the different dispatching policies in an agile way.

Performance measures
Hill (1992) provided a number of performance measures for field service industry: percent uptime, percent of calls on time, and first call effectiveness, to name a few. In line with our discussion on field processes in subsection 5.1.3.2, response time and workforce utilization were chosen as the primary measure of performance in this study.

Response time
As has been discussed earlier, one of the most important operational objectives in the mobile workforce industry is to minimize the response time by creating efficient team structure and

effective dispatching policies. *Response time* is defined as that time from when a call is received to when an engineer arrives at the customer site. For a particular order, the *Response time* is the sum of the *queue time* of the order and the *travel time* of the mobile worker.

- *Queue time* is defined as the time between the arrival of an order and the assignment of a mobile worker. In reality, it reflects the time delay caused by the customer center and the dispatch center, and the picking up time if it applies.
- *Travel time* is calculated by dividing the distance between a mobile worker and a customer location with a predefined travel speed for that worker.

Workforce utilization

Workforce utilization is the percent of time that mobile workers are busy, either traveling to a service call or serving at customer site (Haugen & Hill, 1999).

Parameter	**Specification**	**Relevant Citations**
Response time	Queue time + travel time	Haugen & Hill (1999) Felan & Fry (2001)
Workforce utilization	Percent of time that mobile workers are busy	Hill et al. (1992) Haugen & Hill (1999)

Table 5. 4 Specification of performance measures

5.2.2 Specification of the simulation environment

The simulation building blocks are rooted in the DSOL (Distributed Simulation Object Library) simulation engine because we had opted to use Java as the programming language of choice, and needed a simulation library with constructs that could be easily integrated with the Java code. In particular, we use the DEVSSimulator, a DEVS formalism based simulator, provided by DSOL (Jacobs, Lang, & Verbraeck, 2002). The choice of using DSOL was based on the fact that DSOL is a Java-based open source simulation environment and thus, it is easier to integrate the building blocks into DSOL as it gives considerable freedom for model developers to extend the libraries for domain specific purposes. DSOL offers more than a basic set of libraries for simulation and modeling such as simulators, asynchronous events, random number generators, statistical distribution, experimental frame, animation, graphical user interface, etc.

The simulation engine DEVSSimulator is a DEVS formalism-based simulator for event-scheduling, which means that the objects in a simulation model do not interact synchronously by using direct method invocation, but schedule the method invocations by constructing a simulation event, i.e. asynchronous communication among objects. The simulation event is implemented in a language construct called a SimEvent. The integration of building blocks into a DSOL environment is simply done by adding references from the objects to the simulator. These objects are called *simulated objects*. However, not all the objects in a simulation model are considered to be simulated objects. In DEVS-based simulation, an object is considered to be a simulated object if the object needs to schedule future method invocation. Therefore, there is at least one asynchronous method invocation in the class from where the object is instantiated. The simulated objects are contained in a static *World*, see figure 5.4. In such a way, we can easily add or create other simulated objects, just by making references to the public DEVSSimulator.

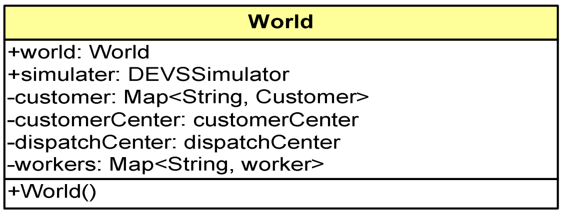

Figure 5. 4 Simulated objects

DSOL is a Java based simulation language that supports all activities but conceptualization in a simulation study (Jacobs et al., 2002). Therefore, a simulation in DSOL is created by writing codes in the Java programming language. An empty simulation model in DSOL is shown below.

```
01 package nl.tudelft.simulation.beams;
02 import java.net.URL;
03 import java.rmi.RemoteException;
04
05 import nl.tudelft.simulation.beams.input.ModelReader;
06 import nl.tudelft.simulation.beams.model.World;
07 import nl.tudelft.simulation.dsol.ModelInterface;
08 import nl.tudelft.simulation.dsol.SimRuntimeException;
09 import nl.tudelft.simulation.dsol.simulators.DEVDESSSimulator;
10 import nl.tudelft.simulation.dsol.simulators.SimulatorInterface;
11 import nl.tudelft.simulation.language.io.URLResource;
12
13 /**
14 * (c) copyright 2006 <a href="http://www.simulation.tudelft.nl">Delft
15 * University of Technology </a>, the Netherlands.
16 */
17 public class BEaMSModel implements ModelInterface {
18 /**
19 * Constructor.
20 */
21 public BEaMSModel() {
22 super();
23 }
24
25 /**
26 * @see nl.tudelft.simulation.dsol.ModelInterface#constructModel
27 *      (nl.tudelft.simulation.dsol.simulators.SimulatorInterface)
28 */
29 public void constructModel(final SimulatorInterface simulator)
30      throws SimRuntimeException, RemoteException {
31
32      World.simulator = (DEVDESSSimulator) simulator;
33
34      URL modelURL = URLResource.getResource("/world_test.xml");
35      new ModelReader().read(modelURL);
36     //to read Model description
37      }
38}
```

In DSOL a model must implement a *ModelInterface* that is defined in the *nl.tudelft.simulation.dsol* package. In addition, the constructor must always be empty so that every replication of a simulation run will start in a new state (Verbraeck, 2004). Line 29 defines the method *constructModel,* which is used to define the variables to be used in the model, the model logic, and any other relevant parameter for the model. Line 30 shows two exceptions that are caught while the *constructModel* method is executed. These are *RemoteException* and *SimRuntimeException*. The *RemoteException* may occur whenever the network linked to the simulator fails, whereas the *SimRuntimeException* can occur whenever a run time exception occurs due to an event that is scheduled in the past or for other reasons. A simulator is initialized in this simple empty simulation model: because this is an empty discrete event simulation model, the simulator implements a *DEVSSimulatorInterface*, which is defined in the *nl.tudelft.simulation.dsol.simulator* package (line 32). This model can be executed in DSOL. To run it, the only thing required is a specification of the treatment, i.e. run length, replication, and other treatment related parameters.

5.2.3 Implementation of the building blocks

In the implementation step, the translation of the building blocks conceptual model into computer language was done in the Java programming language. The use of Java enables easier integration of building blocks into DSOL since DSOL is written in Java. The result of the implementation is a set of simulation building blocks for field service processes.

The suite was constructed according to the class diagram presented in figure 5.5. As we can see from the class diagram the suite consists of a static world containing the instance of the DEVSSimulator and instances of all mentioned building blocks: Customer, Order, Mobile Worker, Customer Center, Dispatch Center, and RoadMap. Besides the representations of the building blocks the suite also includes classes, enumerators and interfaces to support the interaction between the building blocks, and the animation and GUI services. The explanation of the classes is given as follows.

Building block Customer

Customer
The customer class as presented in figure 5.5 represents an actual customer. The attributes of the class consist of a location (Node), a name (String) and an *orderBehaviour* (OrderBehaviour).

The most important methods of this class are the *generateOrder()* and *receiveOrder().* As the name suggests the *generateOrder() method* is responsible for generating orders for the instance of a customer according to the distribution specified in its *OrderBehaviour*, and the *receiveOrder()*method is called when an order is serviced. It sets the delivery time for the statistics.

OrderBehaviour
This class is used to specify the order information of a customer. It holds the different product types a customer can order as well as the distributions for order placement, quantity preference and product preference. This class also has a Boolean *waitForOrder* attribute, which is used to set the condition that the customer can only place an order if a previous order has been served.

Building block CustomerCenter

Customer Center
This represents the instance of the location where the customers place their orders. Its attributes include a name, a list of orders and a distribution for processing times. When an order is received, this class processes the order and sends it to the *DispatchCenter.*

Building block Order

Order
This class consists of every attribute one can expect from an actual order e.g. customer name, id, type of product, quantity, status, etc. For statistical purposes attributes like processing time, delivery or response time and others are included in this class.

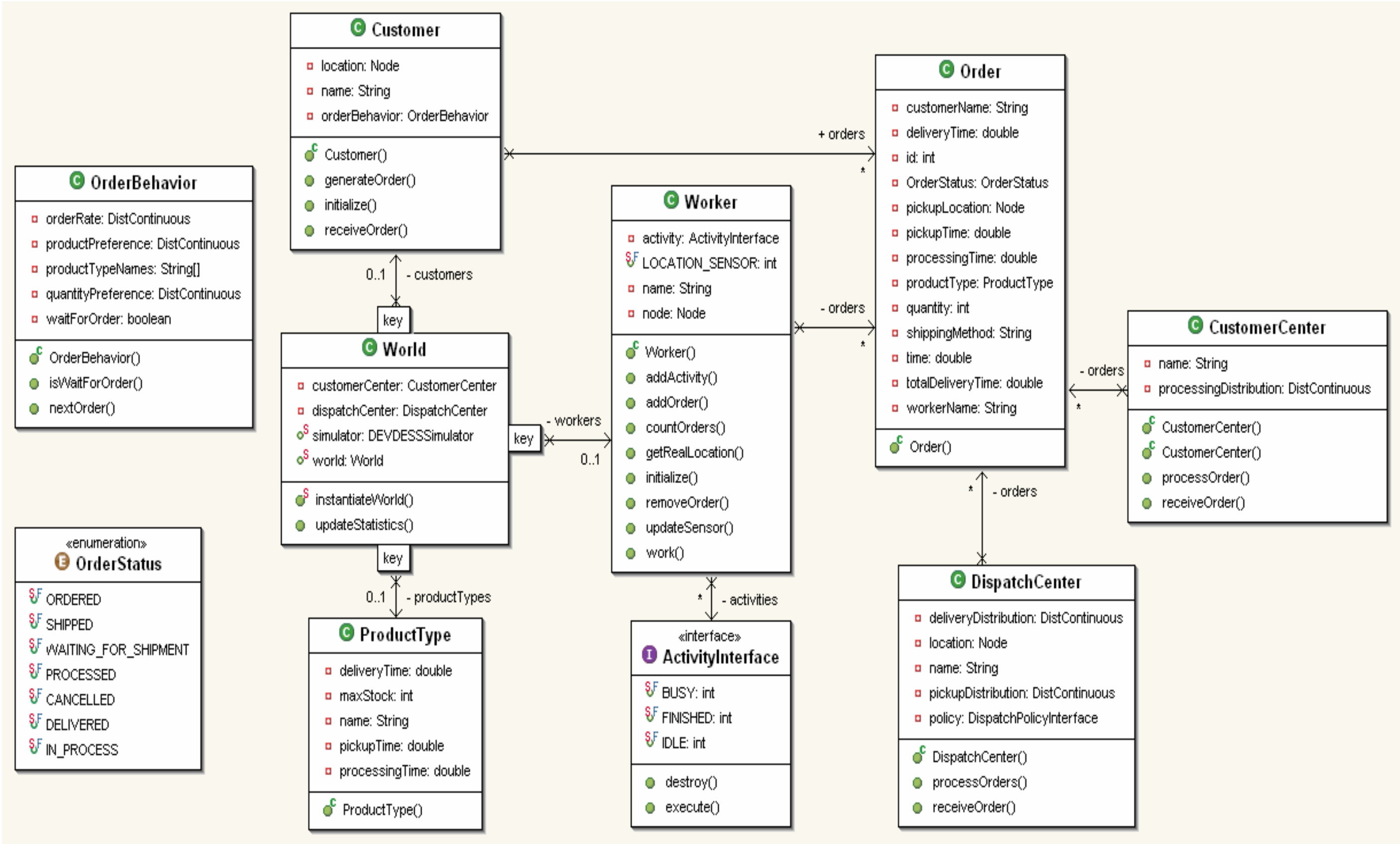

Figure 5. 5 Overview of the class diagram of the suite

ProductType
ProductType represents a product which can be ordered. Its attributes are a name, a processing, pick up and delivery time and a list of required skills to complete an order containing this type of product. In case of the *ProductServing* mode, this class also holds information about the maximum amount of instances of a product type that can be contained in an asset stock (i.e. mobile inventory).

<Enum> OrderStatus
This holds all possible status that an order can take. These are enumerated as: Ordered, InProcessing, Processed, Waiting for Shipment, Shipped, Delivered, and Cancelled.

Building block MobileWorker

Mobile Worker
This class is used to represent a worker in reality with attributes like name, location, skill level, list of orders, asset stock and current activity. When a worker receives an order, the worker object starts its activities by picking up the product ordered and delivers it to the customer.

ActivityInterface
The ActivityInterface is implemented by the *AbstractActivity* class, which has attributes for worker and activity status. The interface specifies the status of the activities of a worker. These are IDLE, BUSY and FINISHED. The *AbstractActivity* Class is extended by three different actions that a worker may perform. As seen in figure 5.6, these actions are *MarkOrderAsShippedActivity*, *TravelActivity* and *WaitActivity*, which are extended by *DeliverActivity*. Each of these actions can trigger an event which is sent to the DEVSSimulator. For example, when *TravelActivity* is called, an event will be triggered by the method of *travel().* The use of this structure allows us to add or remove activities easily, without changing many codes. For example in case the *Idle* mode of mobile workers should be set as a *PatrolMode*, we can implement it by extending the *TravelActivity* class to a *PatrolActivity* class.

Building block DispatchCenter

Dispatch Center
The dispatch centre consists of attributes such as name, location, list of orders, dispatching policy and distribution of processing and picking up time. The orders are received from the customer centre. When an order is received, the dispatch center allocates a mobile worker for the order, according to its dispatching policy. Finally the order is sent to the allocated worker.

DispatchPolicyInterface
The dispatching policy employed by the *DispatchCenter* can be easily simulated with the use of the *DispatchPolicyInterface*, This interface is implemented by the *AbstractDispatchPolicy* class, which can be extended by the specified dispatching policy. The use of the interface allows flexible implementation of multiple dispatching polices.

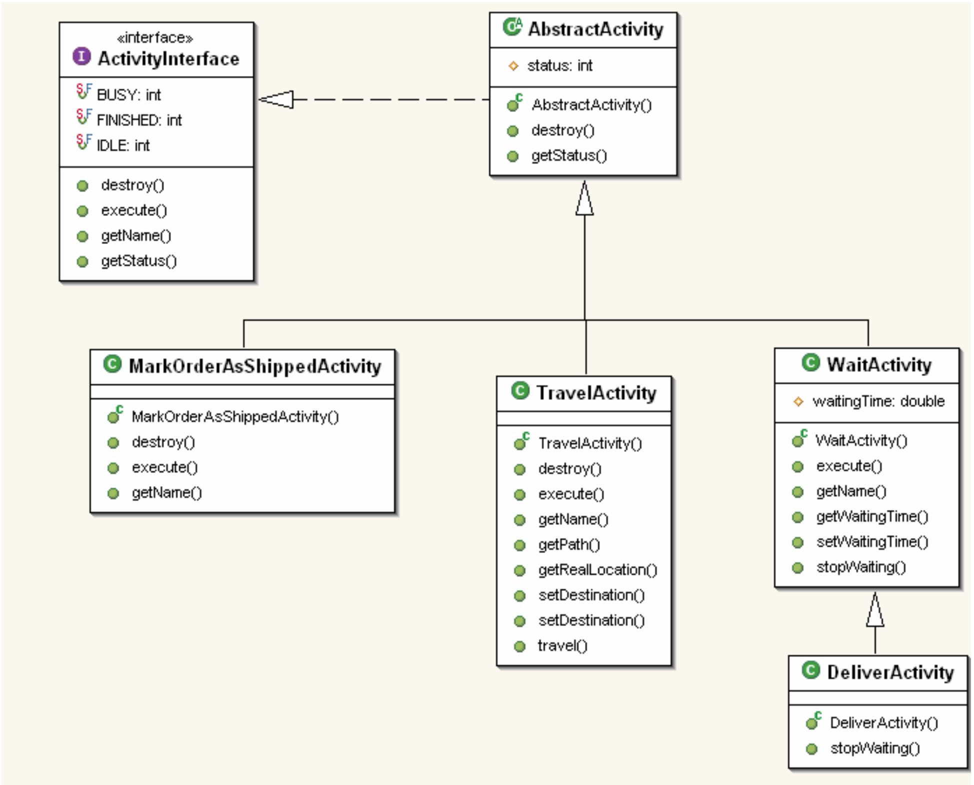

Figure 5. 6 Structure of Activity Interface implementation

PolicyUtility

The *PolicyUtility* class provides different methods to select the dispatching criteria to form a unique dispatching policy. For example, the *findLeastBusyWorker()* method, as its name suggests, is used to select the least busy mobile worker from all mobile workers.

The structure of this building block where four different dispatching policies are implemented as examples, is illustrated in figure 5.7. We take the *SimpleProductDeliveryPolicy* as an example. It is a very simple dispatching policy for the situation that combines a *RoundTripTravel* mode and a *ProductServing* mode, meaning that workers first have to collect product(s) at a certain location before they can deliver them. This policy uses FCFS strategy (see also 5.2.1), and workers are selected at random, regardless of where they are and what they are doing.

For a more advanced dispatching policy that takes more criteria into account, e.g. estimated time of arrive (ETA), we need to specify the policy in a model document, and overwrite the *AbstractDispatchPolicy*. For example, the *KCISmallestETAPolicy* and *G4SmallestETAPolicy* are two advanced dispatching policies that were made for the illustration cases. These will be further explained in section 5.4.

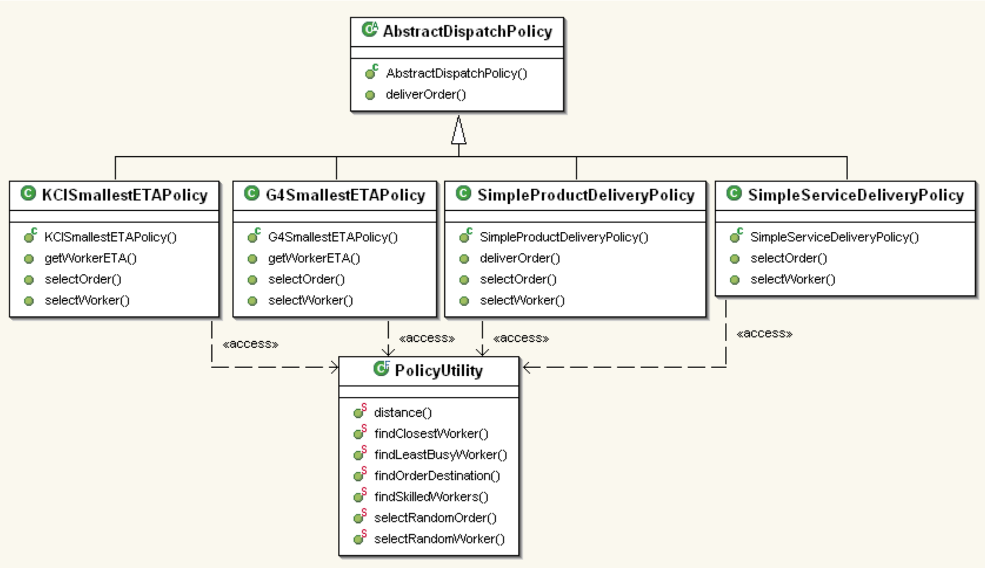

Figure 5. 7 Structure of dispatching policy implementation

Building block RoadMap

The *RoadMap* building block represents a structured roadmap, as shown in figure 5.8. It is constructed from the following classes.

Node
This class represents the actual splitting points of the structured map. This can be seen as the starting and destination points of the roads structures. Its attributes includes a name and a location. The location is represented by a *java.awt.geom.Point2D* object, which is an easily used object for x and y coordinates.

Road
This is a representation of actual roads with the following attributes: name, start node, destination node, length and the speed values. The speed values are specified as a speed forward and a speed backwards. The accessibility of the road can be set in one or two directions.

RoadMap
This is the actual representation of the structured map. It consists of nodes, roads, an IGraph and a pathfinder, see the discussion on the use of *rollerjm-graphs.jar* below. The IGraph is used for modeling the nodes and roads in a structure. The pathfinder is used to determine the shortest path from one node to another. The distance between two nodes is calculated based on the Pythagorean formula. For the determination of the shortest path we use the imported *rollerjm-graphs.jar* file[9].

[9] More information on this library can be obtained from the rollerjm website at: http://rollerjm.free.fr/pro/graphs.html. Last accessed on 20 July 2007.

This library contains useful methods for running the *Dijkstra Algorithm* and the *IGraph, which is* a graph structure that can be used easily to support the determination of the shortest route.

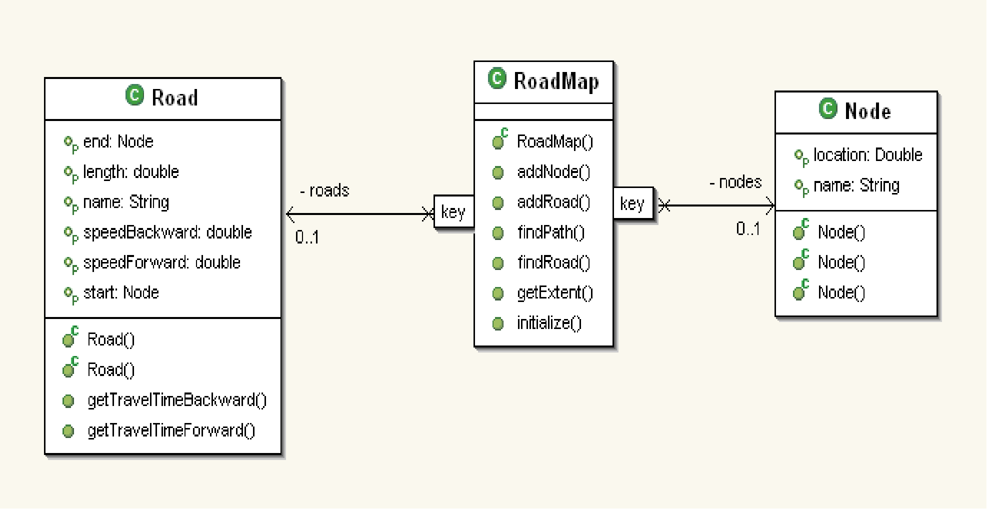

Figure 5. 8 Structure of RoadMap implementation

Animation service and GUI service

To enhance the usability of the simulation suite, animation service and GUI service are included in the development of the suite. The animation service of the suite is built upon the Visualization Library[10]. The set of classes implemented for the animation service are used to generate and represent the coordinates of the operation areas of mobile workers, and the actual locations of mobile workers. The set of classes implemented in GUI service are used to provide a graphical user interface of the suite applications. The GUI service enables the display of the route map and the display of the animation.

All the source codes of the simulation suite, as briefly discussed above, are accessible from http://sourceforge.net/projects/mfssm/, where the suite development has been formulated as an open source project, hosted by Sourceforge under the LGPL license.

Model document

The initialization and finalization of a model can be achieved through editing an XML file. To illustrate the use of this function, it is best to work through examples. Hence, we explain how to specify the road map, product types, customer centre, dispatch centre, customers, workers and all their necessary distributions. An example of model description, written in XML is shown below.

[10] More information on this library can be obtained from the website at http://sk-.tbm.tudelft.nl/simulation/. Last accessed on 20 July 2007.

```
<roadMapReader>map.TxtRoadMapReader</roadMapReader>
<roadMapURL>/roadmap_delft.txt</roadMapURL>
<speed>50</speed>

<productType>
      <name>Therapeutic Surfaces</name>
      <processingTime>1</processingTime>
      <pickupTime>1</pickupTime>
      <deliveryTime>1</deliveryTime>
      <requiredSkill>transport</requiredSkill>
      <maximumStock>8</maximumStock>
</productType>
```

For the road map we need to specify a *roadMapReader* and a *roadMapURL*. The *roadMapReader* class is an implementation of the *roadMapReaderInterface*. The use of the *roadMapReaderInterface* allows us to use different kinds of map readers as long these readers form the necessary objects with the right attributes. The *roadMapReader* class is used to construct all nodes and roads specified in the existing document with the given URL address.

The speed value can be specified as a global variable, as shown in the above example. Alternatively, the speed value can also be specified in the *roadMapReader* when constructing the road objects. Note that for the correct estimation of arrival and other times, the speed value should only be assigned for one direction of the road.

For the specification of the product types we need: *name*, which is also the unique identifier of the product; processing *time*, which is the time needed to process an order; *pick up time*, which is the time needed to load such a product; *delivery time*, which is the time needed to deliver the particular kind of product; the required skill for the product type; and the maximum number of such products can be carried in a mobile inventory.

```
<customerCenter>
      <name>Customer Center</name>
      <!-- the processing distribution is multiplied with a product's
           processing time to get the real processing time -->
      <processingDistribution>
            <className>nl.tudelft.simulation.jstats.
                        distributions.DistUniform</className>
            <param name="a">10</param>
            <param name="a">30</param>
      </processingDistribution>
</customerCenter>
```

The customer center is specified with a name and a processingTime distribution. In the example shown above we chose a uniform distribution with parameters 10 and 30 minutes.

```
<dispatchCenter>
      <name>KCI</name>
      <location>170292027</location>
      <policyClass>nl.tudelft.simulation.beems.policy
                  .KCISmallestETAPolicy</policyClass>
      <!-- the pickup distribution is multiplied with a product's
           pickup time to get the real pickup time -->
      <pickupDistribution>
            <className>nl.tudelft.simulation.jstats.
                       distributions.DistUniform</className>
            <param name="a">10</param>
            <param name="b">15</param>
      </pickupDistribution>
      <!-- the delivery distribution is multiplied with a product's
           delivery time to get the real delivery time (is time spend
           at customer)-->
      <!-- note: actualy this depends on a customer, but we assume it's
           the same for all customers for now -->
      <deliveryDistribution>
            <className>nl.tudelft.simulation.jstats.
                       distributions.DistExponential</className>
            <param name="a">10</param>
      </deliveryDistribution>
</dispatchCenter>
```

The dispatch centre is specified with the following attributes: name; location, which is the name of a node; *policyClass,* which is the dispatching policy to use; *pick up distribution* and its parameters; *onsite service time distribution* and its parameters. Note that in the *NonProductServing* mode, the *pickupDistribution* should be specified as “null”. Both product types and dispatch center contain a specification of onsite service and pick up time. This is also the case with the processing time in the customer center and the product types. We felt that the combination of a global time or delay distribution with a constant value for each product type gives us a greater opportunity to distinguish the different product types not by only name or required skill, but also by the processing, pick up and onsite service times.

```xml
<customer>
	<name>PrivateHospital</name>
	<location>167289040</location>
	<orderBehavior>
		<productTypeName>Therapeutic Surfaces</productTypeName>
		<productTypeName>Therapeutic Temperature</productTypeName>
		<productPreference>
			<className>nl.tudelft.simulation.jstats.
				distributions.DistTriangular</className>
			<param name="a">0</param>
			<param name="b">0.5</param>
			<param name="c">1</param>
		</productPreference>
		<quantityPreference>
			<className>nl.tudelft.simulation.jstats.
				distributions.DistTriangular</className>
			<param name="a">1</param>
			<param name="b">2</param>
			<param name="c">5</param>
		</quantityPreference>
		<orderRate>
			<className>nl.tudelft.simulation.jstats.
				distributions.DistExponential</className>
			<param name="mean">125</param>
		</orderRate>
		<waitForOrder>true</waitForOrder>
	</orderBehavior>
</customer>
```

The customer specification consists of a unique *name*, a *location*, also the name of a node, and an *orderBehaviour*, which is specified by the names of the *product types* this customer can order; the *product preference*, *quantity preference* and *order rate* distributions with all their parameters; a boolean *waitForOrder*, which specifies if a customer can place a new order while still waiting on a previous order.

```xml
<worker>
	<name>Driver Joe</name>
	<node>169294309</node>
	<skill>transport</skill>
	<inventory>Wound Healer</inventory>
</worker>
```

The worker can be specified with a unique *name*, a *location*, *skill* level of this worker and the types of products carried in his mobile *inventory*. The node specified is the location of the mobile worker at the beginning of the simulation.

5.2.4 Verification of the building blocks

During the specification stage, the distributions of the input variables were determined, the model structure was defined and experiment logics were set up to calculate the output variables.

For the purpose of verification of the implemented building blocks, we developed a simulation model for the initial design of the dispatching processes and delivery processes for one of the illustration cases, the G4 case (see details in section 5.3). The simulation model was populated with data that had a statistical distribution.

During the verification phase the simulation building blocks were thoroughly checked to ensure that it functioned correctly, and that it represented the targeted mobile workforce situation. The simulation models were verified to check if they captured the business processes in the conceptual model and whether they provided the required functionality correctly. The structure of the simulation model, the parameters used for simulation model, and the distribution functions used in the simulation model were also checked. Using the 'breakpoint' command errors in the simulation model were checked. The simulation model was exposed to a number of extreme input values and its behavior was analyzed and compared to the expected value.

Based on the reasoning presented in the whole of this section, we summarize that the suite provides a Java library of simulation building blocks which can be used to model and simulate mobile field service processes, especially for dispatching and scheduling processes. It contains objects representing mobile workers, customers, orders, product types, roads, and dispatch centers. A complete model can be specified using the XML input files, which are parsed to instantiate the required objects, their initial conditions, and the experiment configuration.

5.3 Illustration of using the suite in two cases

We applied the suite in two cases that are formulated based on real projects run at LogicaCMG, i.e. the Group4 Falck case and the KCI case. The aim of performing the illustration cases was to show the context in which the suite can be applied and used. The illustration of the application of the suite is given in this section, following the steps for thorough process analysis prescribed in the recipes in subsection 4.4.4.

5.3.1 Illustration case one: Group4 Falck

Group4 Falck (G4) is a leading international security company operating in many countries with some thousand employees. The company provides patrol and alarm response services to their customers. To strengthen their position as market leader in security patrol and response services, G4 considered investing in mobile workforce solutions based on the expectation that the solutions would help them to provide better services for their customers, and also generate savings by promoting greater efficiency in their operations.

5.3.1.1 Step1: identify existing core business processes

There are mainly three kinds of actors involved in G4's business operations, namely the customer, the alarm receiving centre, and G4. The actors and their relationships are shown by figure 5.9.

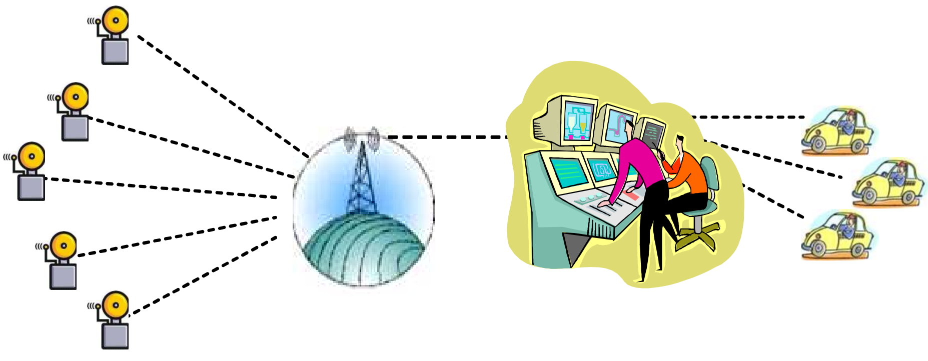

Figure 5. 9 Actors involved in G4 business process

The roles and relations of the actors presented in figure 5.9 are specified as follows.

- Customer: this is the end user who contracts G4 for patrol and response services. The services are delivered through alarms installed in the customer's sites. The alarms are installed by an alarm utilities company, which also owns the alarm-receiving centre.
- Alarm Receiving Centre (ARC). This is a company that provides and maintains alarm systems. In this case, we simply refer to the ARC as the switchboards that receive signals sent by the alarm systems installed in the premises of the customers. After an alarm signal is received at the ARC, the switchboards call the guard command centre (GCC) at G4 requesting them to intervene appropriately at the customer site.
- G4. G4 is responsible for providing security patrol and response services to its customers. Within G4, there are mainly two types of actors, who can be distinguished based on their functions: Guard Command Centre (GCC) and Mobile Guards (MG).
  - GCC: the GCC performs the role of a communication centre in combination with the ARC and a coordination centre within G4. This centre is responsible for planning action after receiving an alarm, communicating all future assignments to the mobile guards, and ensuring rapid reaction to an alarm. In response to an alarm, the GCC assigns and dispatches MG to deal with the situation at the customer's site.
  - MG: Mobile guards are the field workers who receive assignments from the GCC to intervene an alarm situation at a customer site.

The overall business process for G4 is shown in figure 5.10. The process starts when an alarm sends an alert to the ARC. Once the ARC receives the alert, it asks for intervention from the GCC. The GCC responds by assigning a MG to intervene the alarm. The MG first obtains the activation key from the key vault before proceeding with the intervention and patrol, unless an electronic key is available. When the intervention process is finished, the MG is ready for his next assignment.

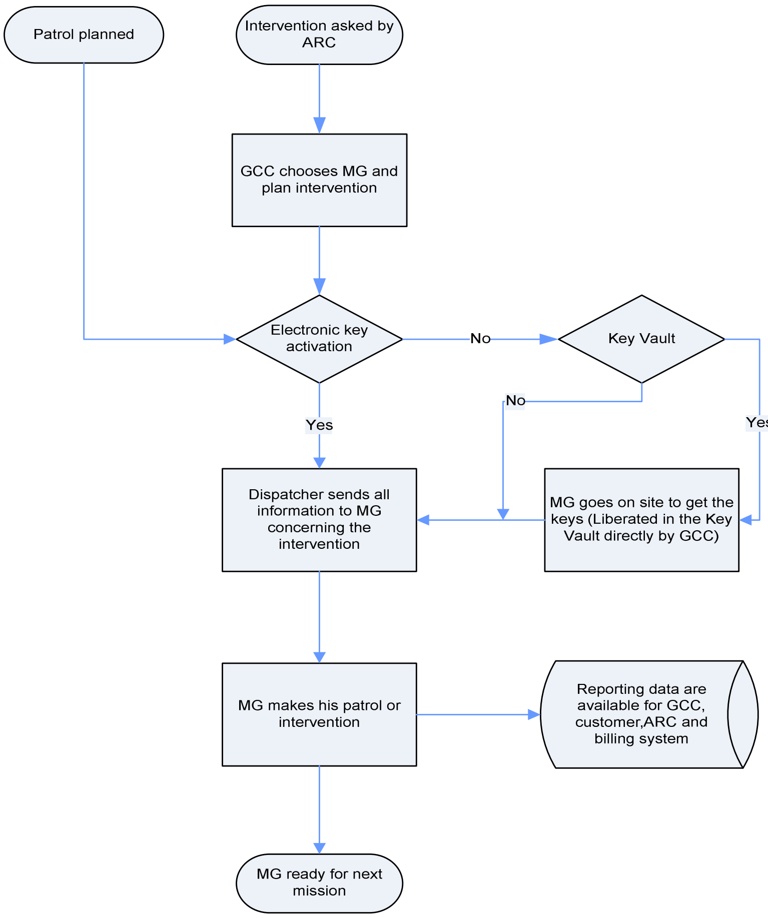

Figure 5. 10 G4 overall business process

5.3.1.2 Step 2: assess potential for improvement by the opportunities of mobile services

The ultimate objective of investing in mobile workforce solutions is to automate and streamline some business processes in G4's operations. The initiative taken by the management of G4 covers the following processes:

- transmission of alarms from remote monitoring switchboards
- service planning, i.e. security guard allocation and dispatching
- remote activation of electronic keys
- registration of invoicing data

The transmission of alarms from the remote monitoring switchboards is a process that is mainly automated, where the alarm signals are sent from systems installed on a customer's premises. The registration of invoicing data is a process that is carried out after the alarm call is dealt with, and is done at the end of an assignment. All these processes have no direct relevance to the mobile worker, and we therefore did not pursue them further.

The service planning process is of interest because it is the process used to plan patrol rounds, to distribute intervention assignments, and to maintain the activation keys. It directly involves business processes that affect the mobile workers. The process can be improved through the use of a mobile solution which would ideally consist of two services. The first service would be used for tracing and tracking the location of a mobile guard through the use of location based services, either through mobile devices installed in the patrol vehicle or via portable devices such as a PDA. The second service would enable electronic key activation through the use of services such as a mobile ticket in the form of a barcode sent to the mobile device of the guard. The barcode would eliminate the need for the guards to get an activation key from the vault before intervening in an alarm situation.

5.3.1.3 Step 3: map alternative business processes based on the results of mobile services

We limit our discussion to the service planning process because it is related to the mobile workers, and hence in line with the objectives of the case study. The major improvement in the service planning process is to support time-critical planning with a dynamic dispatching mechanism. A what-if analysis is needed here to examine to what extent the response time for an alert and the utilization of the mobile workforce will be improved. Moreover, another interesting issue to explore in this case is how the mobile guards can be allocated more efficiently using a new, dynamic, dispatching mechanism.

To elaborate on the processes in which a what-if analysis of the mobile solutions can be performed, we describe the to-be business processes enabled by the new dispatching mechanism. The basic idea is that the electronic key will be activated through the mobile solution and thereby replace traditional key use. The consequence of this is that the mobile guard goes directly to the alarm location, instead of going to the key vault first. Furthermore, mobile devices such as GPS and PDA can be used to establish a real time communication channel between the GCC and the mobile guards, which enables the GCC to track the location of the mobile guards. The real time communication channel allows for the sending and receiving of real time data between the GCC and the MG, e.g. to send time required to finish a current task by the MG to the GCC. The new dispatching mechanism supported by the proposed mobile solution is illustrated in figure 5.11.

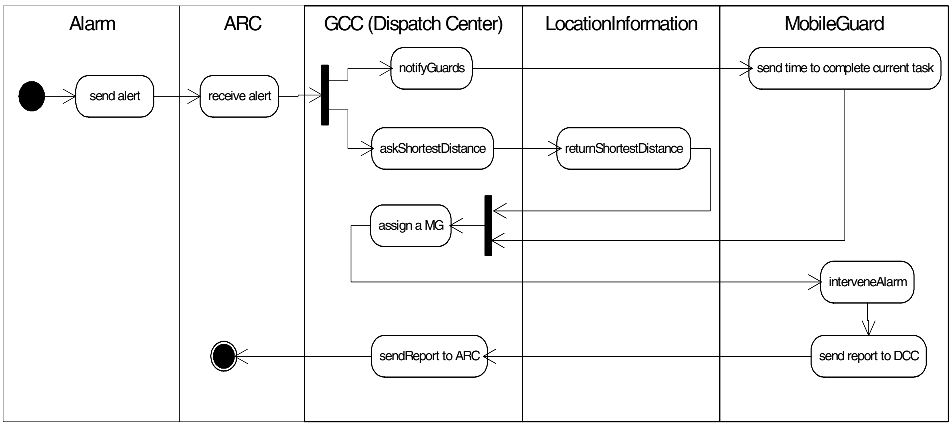

Figure 5. 11 New dispatching processes enabled by the mobile solution

To conclude, the criteria for the new dispactching process are based on the availability of a mobile guard, distance of the mobile guard from the alarm, and the time remaining to complete the current task. The new dispatching process presented in figure 5.11 can be futher explained using the senario illustrated in figure 5.12, as follows.

- Alarm fires an alert.
- GCC notifies all mobile guards regarding the alert.
- At the same time, an application at the GCC calculates the time need to response for each mobile guard based on their distances from the alarms location. For example, from figure 5.13 we can see that the time needed to travel to the alarm location for Guard A, Guard B, and Guard C are 30 minutes, 20 minutes, and 30 minutes respectively.
- Having received the alert notification, mobile guards send, through their mobile devices, the time required to complete their current assignment. For example, from figure 5.13 we see that Guard A needs 40 minutes, Guard B needs 5 minutes and Guard C needs zero time, i.e. he is free.
- A dispatching decision will then be made based on the Minimum Time Required (MTR) to arrive at alarm site for each mobile guard. The MTR is the summation of the remaining time for the current task and the travel time to the alarm site. The guard with the minimum MTR is dispatched to the alert. In figure 5.13, the MTR for Guards A, B and C is 70 minutes, 25 minutes and 30 minutes respectively.
- Based on the MTR, the GCC assigns guard B to intervene the alarm and not guard C.

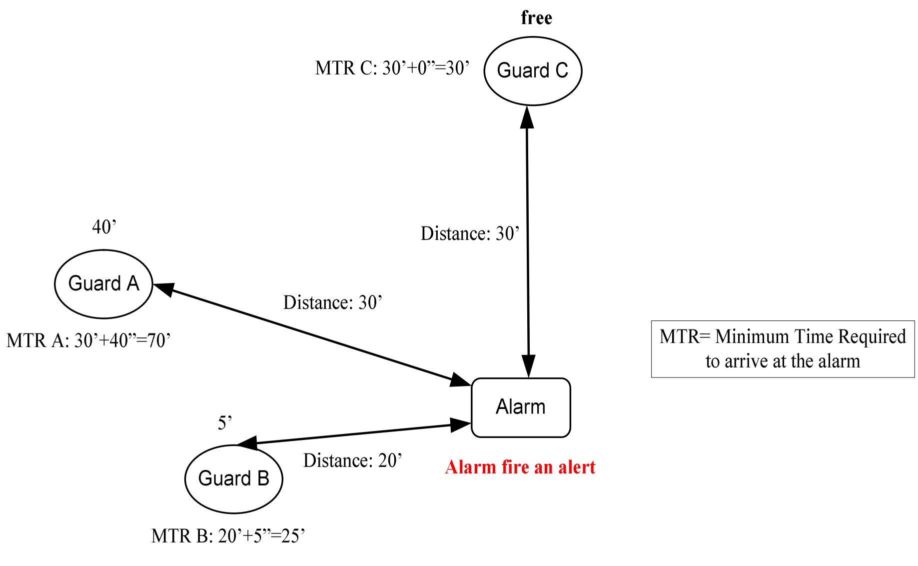

Figure 5. 12 : A scenario of New dispatching policy

5.3.1.4 Strep 4: analyze alternative business processes by simulation

The simulation suite was primarily to used to in this step. In the illustration case, we focus on explaining how the suite is used to develop the simulation model, instead of explaining how the simulation model is used to analyze business proceses, which will be stressed in the second illustration case.

We argue that simulation models can be developed with the use of the simulation suite, and can be used to study the new dynamic dispatching processes enabled by mobile services for the G4 case. Next, we describe the procedures to follow to devlope the simulation model with the use of the suite.

Concepualization using building bocks

Firstly, the concepual model of the dipatching processes of the case need to be mapped into the bulding blocks provided by the suite. This results in the determination of the building blocks to be used for simulation model development, see table 5.5.

Building blocks	Representation in the case
Customer	The customer building block is represented by the actual customers of G4 group in this case. They are the instances which raise alarms and thereby call for interventions. .
Order	The order building block is represented by the alarm event, which is the single type of order recognizable in this case. We assumed that there are no different priorities attached to the alarm events.
Customer center	The Alarm Receiving Center (ARC) is modeled as a customer center, since the alarms are first sent to the ARCs.
Dispatch center	The dispatch center building block is represented by the guard commanding center (GCC) in this case
Mobile worker	This block is logically represented by the mobile guards, as they are the ones that receive assignments from GCC and conduct tasks at the customer sites.
RoadMap	This building block is fed with a simple map for the purpose of demonstrating our concept, and is specified in *roadMap.xml*. This file is read by the *mapReader* class in the road package.

Table 5. 5 Representation of the building blocks in the case

Specification of the building blocks

To specify the selected building blocks in the context of the case, some considerations need to be made and a few examples are discussed next.

Customer

In this case, we need to define a number of customers separately, with a name, a location and an orderBehavior. The orderBehavior of each customer concerns only the distribution value of inter-arrival time of order i.e. order rate in this case; product prefernce and quatity preference are not valid in the case and hence need to be set to a constant value, e.g 1. The attribute waitForOrder, which defines whether the customer has to wait to place a new order until the previous one is delivered , should be set true, becasue in this case multiple alarms can not be triggered by one customer at the same time.

Order

The order building block is represented by the different product types which can be ordered. The product types are generaly defined by a name, a required skill, a maximum stock value, a processing, a delivery and a pick up time.

The maximum stock value is the number of instances of a product that can fit in the mobile stock of a mobile worker, and it is not necessary to be specified because it is not required in the case. The processing, delivery and pick up time are used to differenciate the time attributes of variable products; as there is only one product type, i.e. Alarm, in the case, all time attributes can be set to a constant value, i.e. 1.

CustomerCenter
The customer center need to be defined by a name and the processing distribution in this case.

MobileWorker
Mobile workers need to be defined by a name, an initial location, skills and the product types carried in their mobile inventory. In this case we need to define a number of mobile workers, each with an initial location at the dispatch center and a common skill, i.e. guard. As discussed earlier, no product is carried by mobile worker in this case, therefore specification of product types carried in their mobile inventory can be left out.

Roadmap
This building block is represented by a class name, defining the roadMapReader to use, a URL, defining the location of the roadmap data to read, and an optional default speed value for all roads in the roadmap. The roadMapReader need to be an implementation of the defined roadMapReaderInterface, and the output of the reader need to be in the form of nodes and streets as defined in the building block. In this case we need to define a roadmap in an XML file, and set a defaul speed value for all the roads, e.g. 30 kilometers per hour.

DispatchCenter
The dispatch center should be defined with a name, a location, a delivery distribution and a dispatching policy (by means of refering the class name of the dispatching policy). Because there is no product need to be loaded in this case, pick up distribution is not necessary to be considered and therefore needs to be set "null". A dispatching policy suitable for the case needs to be specified (see the discussion next).

DispatchingPolicy
A dispatching policy needs to be specified which captures and reflects the core features of the dispathcing processes of the case. A dispatching policy is an implementation of the DispatchPolicyInterface within the suite. The interface defines the methods selectOrder, selectWorker and deliverOrder, which must be implemented in the dispatching policy. When defining a new dispatching policy within the suite for this case, we may consider to use an AbstractPolicy class, which implements the DisptachingPolicyInterface and is extended by all dispatching policies.

In addtion, the PolicyUtility class can also be used for defining a dispatching policy, which contains some utility methods, such as selectRandomOrder, selectRandomOrder and selectLeastBusyWorker. Some specificaiton considrations in the case are provided next as examples.

- *selectOrder*: This method returns the next order to be processed by the dispatch center. In this case the First Come First Serve (FCFS) approach is applied, so that the method need to return the first order in the dispatch centre's order list.

- *selectWorker*: This method returns a mobile worker which will be assigned to a given order. In this case, we need to assign the mobile workers according to their Estimated Time of Arrival (ETA). The mobile worker with the smallest ETA is selected. The mobile worker's

ETA is calculated by the method getWorkerETA, provided in the Policy Utility classs of the suite.

- *deliverOrder*: As mentioned earlier this method is not defined in a dispatching policy, but in the AbstractPolicy class extended by a dispatching policy. This method *delivers* the order to the selected mobile worker. In the case we just need add the order to the mobile worker's order list.

Implementation of the dispatcing policy

Next, we illustrate how the specified dispatching policy is implemented in this case. The dispatching policy is an extension of the *abstractDispatchingPolicy*, which implements the *dispatchingPolicyInterface*. This means that the methods *selectOrder* and *selectWorker* must be implemented in the dispatch policy. As was mentioned earlier, the selection of orders goes according the *FCFS* policy, so the first order in the list is selected. To select a worker to deliver the order we use a policy based on the smallest Estimated Time of Arrival (ETA). The implementation is shown using pieces of code below.

```
/**
 * @see nl.tudelft.simulation.beems.policy
 * .DispatchPolicyInterface#selectWorker(java.util.List,
 *  nl.tudelft.simulation.beems.model.Order)
 */
public Worker selectWorker(List<Worker> workers, Order order) {
      // Get worker with smallest ETA
      Worker worker = null;
      double ETA = Double.MAX_VALUE;

      for(Worker current: workers){
            double workerETA = getWorkerETA(current, order);
            if(workerETA < ETA){
                  ETA = workerETA;
                  worker = current;
            }
      }
      return worker;
}
```

The method *selectWorker* selects a worker based on the smallest ETA. To determine a workers ETA the method *getWorkerETA* is called upon. This method determines a workers ETA for a new order by adding *the time needed to finish all scheduled tasks*, in the orders list, to *the time needed to travel to the new orders location*. The following pieces of codes were taken from the *G4SmallestETAPolicy* class. The full implementation of this class is included in appendix 3.

```
    private double getWorkerETA(Worker worker, Order order){
        double ETA = 0;
        /**
         * if worker isn't busy, ETA is the time needed to reach the order
         * destination, as the speed values are constand, there's no
         * difference between distance and time needed to cover the distance
         * for the calculation of the ETA
         */
        if(worker.getActivity() == null || worker.getOrders().isEmpty()){
            ETA = PolicyUtility.
                distance(worker.getRealLocation(), PolicyUtility
                .findOrderDestination(order).getLocation());
        }else{
            List<Order> orders = worker.getOrders();
            Order currentOrder = orders.get(0);

            //add remaining time for current order
            if(worker.getActivity().getName().equals("Traveling")){
                ETA = PolicyUtility.distance(worker.getRealLocation(),
                    PolicyUtility.findOrderDestination(currentOrder)
                    .getLocation()) + currentOrder.getDeliveryTime();
            }
            else if(worker.getActivity().getName().equals("Waiting")){
                WaitActivity temp = (WaitActivity) worker.getActivity();
                ETA = World.simulator.getSimulatorTime()-
                    temp.getStartTime();
            }

            //add time for remaining orders
            for(int index = 1; index < orders.size(); index++){
                Order current = orders.get(index);
                ETA += PolicyUtility.distance(PolicyUtility
                    .findOrderDestination(currentOrder)
                    .getLocation(), PolicyUtility
                    .findOrderDestination(current)
                    .getLocation())
                  + current.getDeliveryTime();

                currentOrder = current;
            }

            // finally add time needed to travel from last order
            // destination to new order destination
        ETA += PolicyUtility.distance
            (PolicyUtility.findOrderDestination(currentOrder)
            .getLocation(), PolicyUtility
            .findOrderDestination(order).getLocation());
        }
        return ETA;
    }
```

Model construction
Assumptions about the initial conditions of the model are further made, and as a result the values of varied input parameters are determined as presented in appendix 3. A *Model* that implements *ModelInterface* of DSOL was created, and the model was defined in an XML file, i.e. *world_G4.xml*. As indicated earlier, this XML file reflected all the specificaitons we had made on the buidling blocks used. Moreover, the simulation model was constructed by instantiating the building blocks. Any building blocks that are not required to fulfill a given function during the simulation run were not specified. Figure 5.13 shows the results of running the simulation model based on the parameters we specified.

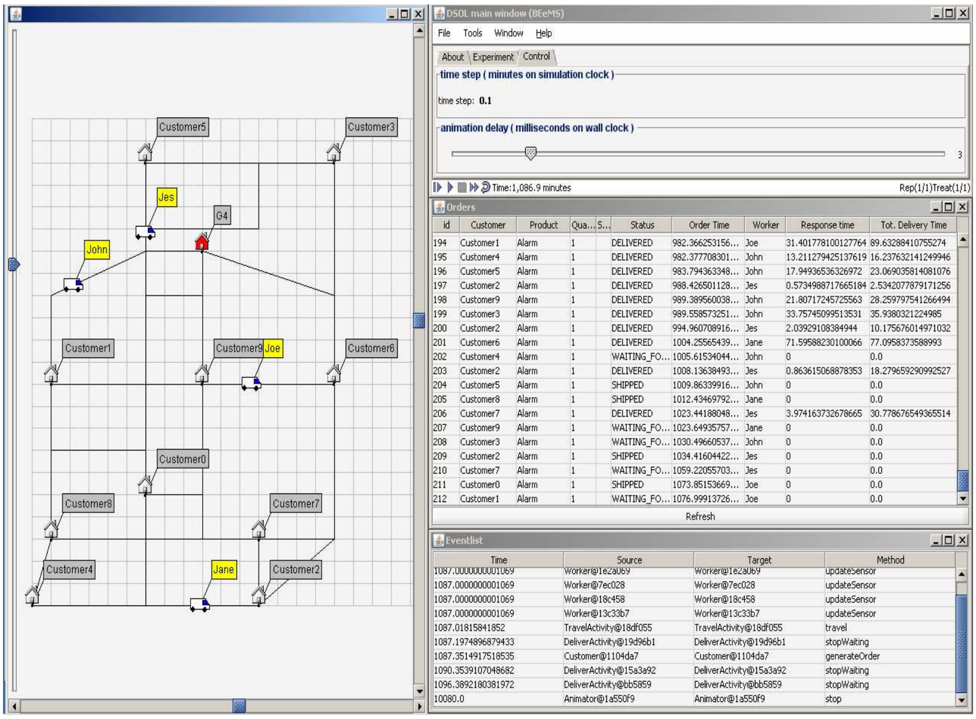

Figure 5. 13 Runtime view of the mode

In the map window, the locations of the customers and the dispatching center are shown. The movement of the mobile workers is also animated. The visualization of the map can be zoomed in or out for a detailed view or overview of the area of operation of the mobile workers. This map visualization demonstrates the basic functionality of mapping software embedded within a mobile solution that allow for visibility into the workers' locations. Through the function, we can show more explicitly how the location-based data serves as critical input for optimization solutions that calculate dispatching schemes.

The running speed of the simulation can be adjusted in the control panel. This function allows a step by step diagnosis of the details of the order event and its execution activities through the orders window which shows all detailed information on the orders, such as incoming time, status, type of product, quantity of products ordered, mobile worker assigned, response time, and total delivery time. We take the alarm with an id 200 as an example. The alarm comes from the customer 2, a mobile worker Jes is assigned to the alarm, and he arrives in the customer site in around 2 minutes. The alarm is resolved within 10.1 minutes in total. We claim that the information shown in the order window provides an opportunity to gain insight into the new dispatching situation.

Verification and experimentation

Verification and experimentation are the two steps commonly followed to finish a simulation study. The verification of the simulation model of the case was done in the way discussed in subsection 5.2.4. As we see, the process also served as a means to verify the building blocks in general. The basic measurements taken during the course of the simulation are the response time to the orders and the utilization of each mobile worker. However, we will not proceed with discussing the experiment results of the simulation model. We think the statistic function provided by the suite, and the map visualization function, is better illustrated in the next case.

5.3.2 Illustration case two: KCI International

KCI International is subsidiary of KCI[11] (Kinetic Concepts, Inc.), a global medical technology company with leadership positions in advanced wound care and therapeutic surfaces. KCI's main business is the renting of medical appliances to customers, mainly hospitals. Given that renting is the company's main business, the benefits derived from operating the business are highly dependent on invoice turnovers. The more efficient the rental processes are operated the more the company benefits, which makes the role of deliverers who deliver orders very important.

5.3.2.1 Step 1: identify existing core business processes

There are two key actors that play an important role in the business operation, namely the customers and KCI:

- Customers: These are the end users who rent medical appliances from KCI. Their main function in the KCI business process is to issue orders for medical appliances.
- KCI: KCI is responsible for satisfying customer orders, and this is done through three important actors: Customer Service Department, Dispatching Department, and Deliverer.
  - Customer Service Department: receives order details from customers.
  - Dispatching Department: receives order details from the customer service department, and makes a dispatch plan. It also allocates the resources required to meet the customer orders.
  - Deliverers: these are mobile workers who receive assignments from the dispatching department to deliver medical appliances to the customers.

The business process starts when a customer orders a product. The order details include the product type, number of product, customer location etc. Having received the order, the dispatcher allocates a product and a deliverer for the order. There are two main types of order:

- *Normal order*: this order arrived day (s) before its delivery time. These are the orders received by the dispatching department at the beginning of every working day.
- *Emergent order*: this type of order must be delivered as soon as possible, and can be received any time during the working hours of a day.

For administration purposes, an order is usually processed directly by the customer service department. The detailed order information then is sent to the dispatching department, which makes a resource allocation plan and a deliverer schedule. Finally, a deliverer is assigned to deliver the medical appliances to the customer. At the customer's site, the deliverer hands the products to the customer, where some processes such as the installation of medical appliances might take place.

After receiving the medical appliances, the customer signs the POD (proof of delivery). The POD is brought by the deliverer to the central office where it is processed further, for example by matching the order with the POD in the financial department, data entry, etc. Finally, an invoice is issued to the customer. The dispatching and delivery activities are critical in this kind of business, and the better the dispatching and delivery process, the shorter the cycle to issue invoices. The overall business process for KCI is presented in figure 5.14.

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[11] http://www.kci-medical.com/kci/corporate last access on 27 June 2006

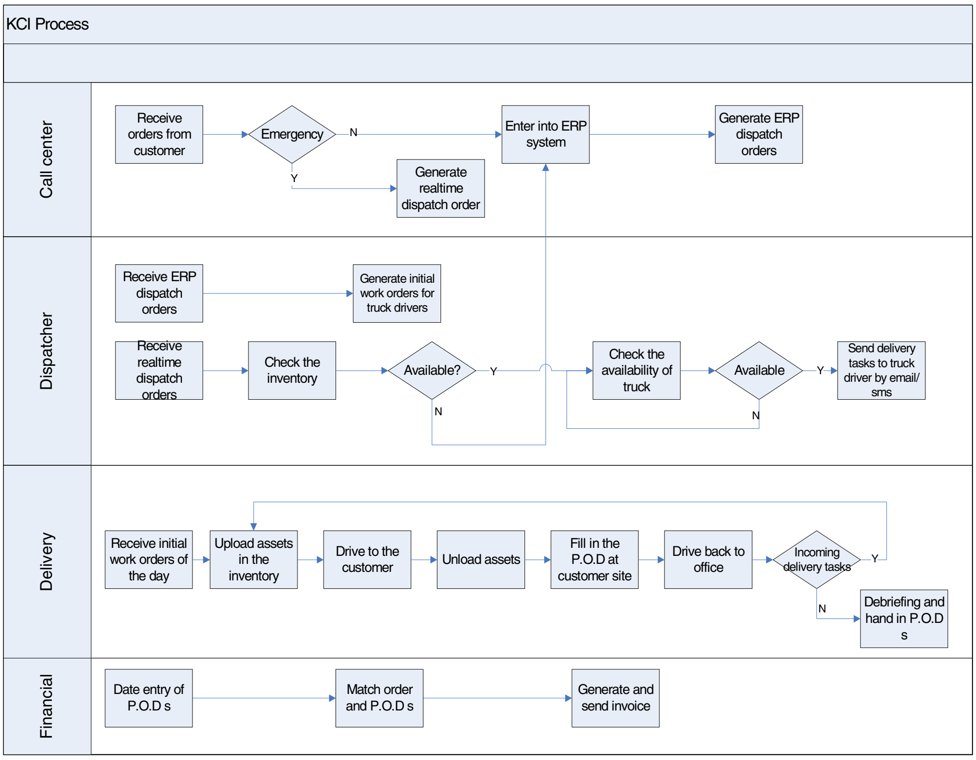

Figure 5.14: KCI overall business process

5.3.2.2 Step 2: assess potential for improvement by the opportunities of mobile services

The major reason for KCI's provision of mobile solutions is to ensure that medical appliances are dispatched and delivered efficiently to meet their service level agreements with their customers, especially regarding to the fulfillment of emergency orders. The following initiatives were taken by the management of KCI.

- The mobile solutions should allow single entry data input to improve the quality of the data based on up-to-date information, e.g. current stock status and less time consumption for correcting data input.
- The mobile solutions should enable immediate data entry, which in turn will allow quicker invoicing. This includes the automation of POD entry by the deliverer so that the data does not have to be processed further.
- The mobile solutions must reduce paper work.
- The mobile solutions should help in the scheduling and allocating of deliverers.

We argue that the last initiative, helping in the scheduling and allocation of deliverers, is the most important and most challenging given the complexity and uncertainty in the current operations. For example, situations in which all the deliverers are working outside the office when there are emergent orders occur often, and are expected to occur more frequently. Further, a solution may be provided by the delivery vehicles carrying several, commonly ordered, spare medical appliances, during a planned trip. In this way, a delivery vehicle can be assigned to go directly to the customer site from anywhere, which can save it traveling to the inventory to load appliances. However, this process is only possible on the condition that the necessary administration procedures, e.g. reporting and registration, are accessible to the deliverer anywhere. A type of mobile ERP (terminal) system is therefore proposed as a solution to enable the new business processes.

In addition, a location based service is also needed to track the real time locations of deliverers, which is expected to help in assigning the right deliverer to deliver emergency orders quickly. This is explained further in the next subsection.

5.3.2.3 Step 3:map alternative business processes based on the results of mobile services

Our focus in this case was on the business processes related to dispatching and delivery. A sequential diagram was used to capture the nature of the dispatching process at KCI, as shown in figure 5.15. The input to this process is the order details from the customer service department.

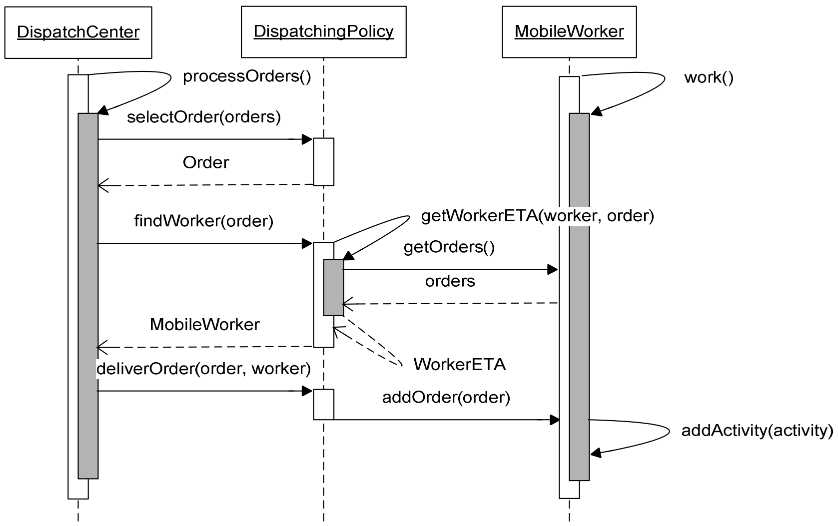

Figure 5. 15 KCI's deliver allocation process

The mobile services enable real time communication between the dispatching department and the deliverers, and provide the ability to track the location of deliverers. The new dispatching criteria are based on the availability of a deliverer, availability of a product in his mobile stock, his remaining time required to complete the current task, and his distance from the following task site. The dispatching criteria used here are further explained with following scenario as illustrated in figure 5.16.

- The customer issues an emergency order for one product x.
- After receiving the emergency order, the dispatcher notifies all deliverers of the incoming order.

- Deliverers respond by sending the data regarding the availability of the product in their vehicles. As shown in figure 5.16, for each of the deliverers A, B, and C, the number of product x are zero, nine, and three respectively.
- Deliverers send information regarding the time needed to complete their current assignment. The value is equal to zero for deliverer A meaing he is currently free. For deliverer B and C the times are 5 minutes and 50 minutes respectively.
- The dispatcher knows the location of each deliver using the location based service, and it is possible for him to check the distances between the customer and each deliver.
- The dispatching decision is made based on the Estimated Time of Arrival (ETA) at the order site. The ETA for a particular delivery is the summation of his travel time to the site and his remaining time for the current task. In the scenario, the ETA for each deliverer A, B, C is 50, 15 minutes, and 65 minutes respectively.
- Based on the ETA the dispatching department assigns deliverer B for the order.

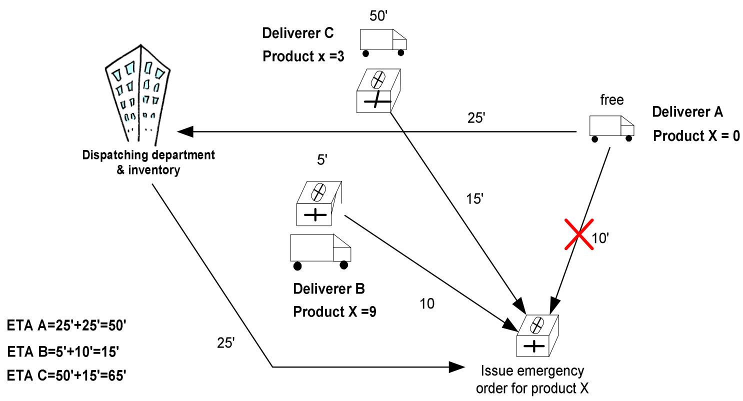

Figure 5. 16 A scenario of new dispatching policy

To implement this case, we gathered information on important actors and their relations, and the potential dispatching process enabled by mobile services, i.e. what-if process. An important design issue here regarding the what-if analysis is the possible consequences of the new processes. It is important to provide indications of the expected result, e.g. response time for an emergency order. This knowledge is significant for designing the mobile solution, and also for decision making regarding its implementation investment. Based on these observations, we can clearly see the need to enable the decision makers to gain insight into the dispatching and delivery process of orders in the new situation using simulation.

5.3.2.4 Step 4: analyze alternative business processes by simulation

Grounded on the experience we gained from the first case, the simulation of this case is simple. The same procedures are applied, the difference is mainly in the dispatching policy. We will focus on illustrating how we simulated the dispatching policy in the case and on the final run view results. A discussion on the assumptions and the specification of initial conditions can be found in appendix 4. For example, as input data, each customer is assigned an *OrderingBehavior*, where information such as the product preferences and order rate distribution is specified.

Implementation of the dispatching policy

To simulate the what-if dispatching processes in this case, we implemented a corresponding dispatching algorithm to determine the order in which the tasks are performed and to assign the workers to the tasks. During the simulation run, each mobile worker performs tasks according to his schedule. The schedule is dynamically generated. A new task is generated for a mobile worker each time when there is a new event related to this mobile worker, such as when he finishes his current task and becomes available, or when a new order requires the worker's matching resource, i.e. the stocks in his vehicle (or mobile inventory).

Modeling of this dispatch policy was implemented in the *KCISmallestETAPolicy* class. This policy requires an implementation of the methods *selectOrder* and *selectWorker*, and we use the FCFS approach to select the orders and the smallest ETA approach to select the mobile worker. The implementation is shown using pieces of code as follows.

```
        /**
         * @see nl.tudelft.simulation.beems.policy
         * .DispatchPolicyInterface#selectWorker(java.util.List,
         *      nl.tudelft.simulation.beems.model.Order)
         */
        public Worker selectWorker(List<Worker> workers, Order order) {
              // Get worker with smallest ETA
              Worker worker = null;
              double ETA = Double.MAX_VALUE;

              //only check the ETA of workers with required skill
              List<Worker> skilledWorkers =
                     PolicyUtility.findSkilledWorkers(workers, order);

              for(Worker current: skilledWorkers){
                     double workerETA = getWorkerETA(current, order);
                     if(workerETA < ETA){
                            ETA = workerETA;
                            worker = current;
                     }
              }
              return worker;
        }
```

As we can see above, a check for skilled mobile workers was included. As in the F4 case, the method *getWorkerETA* determines the ETA of a given mobile worker. (The full implementation of this method is included in appendix 4.) The main difference with the method in the G4 case is that a test for sufficient stock is included. If this test shows stock is available in the vehicle, the deliverer can go to the customer directly; otherwise he has to load the product first. This can make a big difference in the ETA.

Runtime view

The runtime view of the simulation model is given by figure 5.17. For ease of analyzing the data on the response times, we included information such as customer, status, product type, quantity and mobile worker in the orders window. This information supports the decision makers in gaining insight into how the dispatching policy influences the workload or activities of a mobile worker.

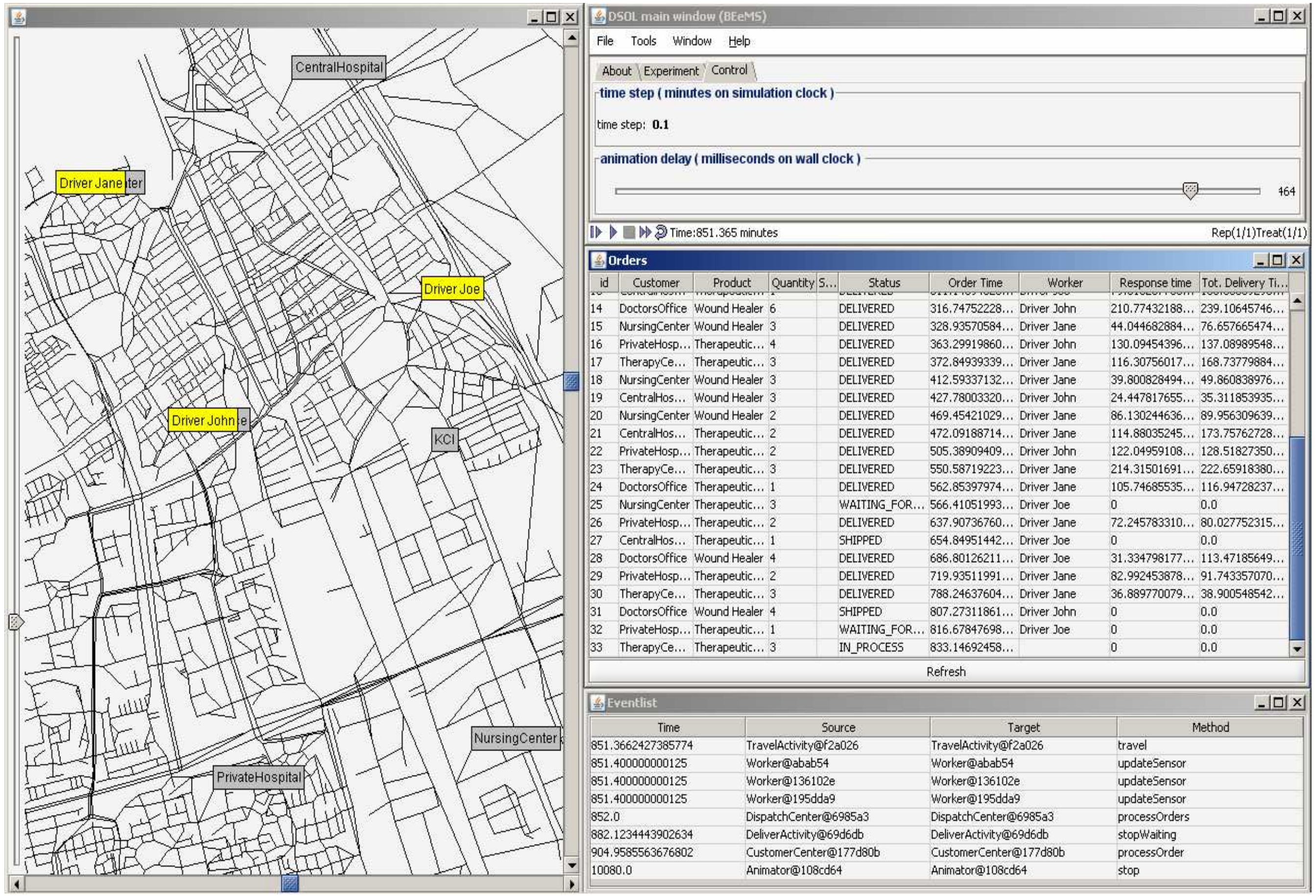

Figure 5. 17 Runtime overview

The roadmap used in this simulation model was constructed based on real GIS data from a region in which KCI operates. The raw GIS data was translated into a format that is easy to read for the model. For instance, the raw data contains real maximum traffic speed values for every roads, but since our implementation was only for demonstration purposes, we chose not to use those values for simulation and added a general speed value of for all the roads. This speed was set at approximately 30 km/hour. The formatted data is read by the *mapReader* in the *txtRoadMap.jar* file. The eventlist window is also included in a run time view, which is mainly for the purpose of model verification and validation. In addition, the information obtained in the eventlist window also provides insights into the flows of information within the business processes.

During the simulation run, it is also possible to check the real time statistics, where the results obtained from the performance indicators are shown. Figure 5.18 is used as an example to illustrate the function of statistics embedded in the suite. In this example, utilization of each mobile worker during the simulation run is measured in the way we specified in subsection 5.2.1 (see the charts in the second and the third row). As the charts indicate, worker Joe kept busy around 50% of her time, and worker John kept busy around 40% of his time in this system. Alternatively, we also presented, in response to the interests of the project manager of the KCI case, the statistics regarding the number of orders scheduled for each worker every time unite (see the charts in the first row). These charts provide another way to indicate the workloads of each mobile worker. We would like to stress that the statistics function provided in the suite is not limited to the example shown here, and it can be used to present more results by extending the statistics class of the suite.

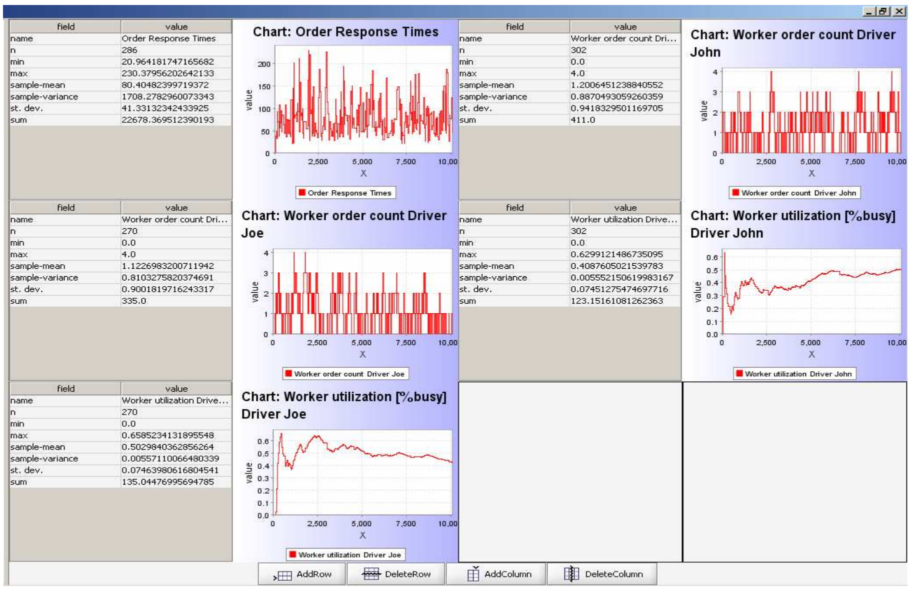

Figure 5. 18 Screenshot of statistic results

In all cases the n stands for the number of times that statistical object is called upon. In case of the response time statistics the n stands for the number of delivered orders. The mobile worker statistics, worker utilization and order count, are called twice per received order. Therefore the n stands for the number of received orders (per mobile worker) multiplied by two.

Experiments
In a cycle of simulation study, experiment and solution finding are the important steps after the simulation model was constructed. Hence, experimentation with the simulation model was done to illustrate the full application of the suite in this case.

In addition, the experiments were included here to provide further support for our arguments on the three functional requirements for the suites, as defined in chapter 4, subsection 4.5.2. The details of our arguments are provided in the next subsection, 5.3.3.

Five scenarios were designed for the purpose of the experiments.

The first one reflected the general what-if dispatching processes supported by the use of location based services, as specified in appendix 4. The second scenario was designed for experimenting the capacity of the new service system with varied number of workers. The third scenario was designed for experimenting the capacity of the new service system with varied order rate of the customers.

- **Scenario 1**: This scenario consists of the experiment variables specified in appendix 4.
- **Scenario 2**: On the basis of the first scenario, the amount of the mobile workers was reduced by one. In this scenario, it is expected an increase of the mean response time and the average workload.
- **Scenario 3**: Also based on the specifications of the first scenario, the scenario 3 was specified with a smaller value of the inter-arrival time for the orders. In comparison with the results from the first scenario, the results of this scenario should lead to an increased mean of the response time and workload for the mobile workers in general.

Experiments	**Response time (mean)**	**Utilization of mobile workers (mean)**
Scenario 1	44.46 minutes	Jane: 11.7%
		Joe: 11.9%
		John: 14.8%
Scenario 2	50.57 minutes	Jane: 26.8%
		Joe: 26.9%
Scenario 3	47.84 minutes	Jane: 26.7%
		Joe: 5.6%,
		John: 18.7%

Table 5. 6 Experiment results of scenario 1, 2, and 3

Looking at the experiment results in table 5.6 we see that our expectations for the experiment results were confirmed. In scenario 2 we see that less mobile workers causes the mean response time and workload to be increased. In scenario 3 we see that more placed orders increases the mean response time, and increases the workload for two mobile workers among three. It is interesting to observe that the utilization of mobile worker Joe is largely decreased from 11.9% to 5.6%, which means less orders are assigned to him. An explanation for this result is given below.

As we discussed in sub section 5.3.2.4, the orders are assigned to mobile workers according to their ETAs. The ETA of a mobile worker is influenced by his location, statues, and mobile stocks. Mobile worker, Joe, has fewer orders assigned than the other two mobile workers means his ETA is in most cases higher then others. Looking in detail, we find that it is caused mainly by the specification of Joe's mobile stock that the products carried by him are ordered less often than those carried by other mobile workers.

To support our explanation, we designed the fourth scenario, in which Joe's mobile stock is specified to contain frequently ordered products. As we can see in the results, the modification lead to a higher utilization value of mobile worker Joe.

- **Scenario 4**: This scenario was based on the specification of scenario 3, and we changed the mobile stock setting of mobile worker Joe. This scenario was a supplement of scenario 3, and was used to support our argument on the reasons for the low utilization of mobile worker Joe in scenario 3.

Experiments	**Response time (mean)**	**Utilization of mobile workers (mean)**
Scenario 4	49.45 minutes	Jane: 13.8%
		Joe: 21.0%
		John: 34.4%

Table 5. 7 Experiment results of scenario 4

The suite is not only useful to simulate what-if scenarios, but also as-is scenarios. To illustrate this, we designed a scenario based on the old dispatching processes of KCI case. The experiment of this scenario requires some changes need to be made in the specification of the simulation model we developed for the previous scenarios, for example, mobile workers carry no stocks and follow a return mode, i.e. after each delivery they need to return to the inventory. In this scenario dispatching of the mobile workers is not based on ETA, but a random selection of available mobile workers at a moment.

- **Scenario 5**: The settings in this scenario reflect the old dispatching processes of the KCI. Except for some experiment variables and the dispatching policy, the input specifications are same as the scenario 1.

Experiments	**Response time (mean)**	**Utilization of mobile workers (mean)**
Scenario 5	51.64 minutes	Jane: 6.3%
		Joe: 27.4%
		John: 10.4%

Table 5. 8 Experiment results of scenario 5

As we see, the utilization of mobile workers in this scenario differs from each other to large extent, comparing to the result of scenario 1. This is because in the old situation, the available mobile workers are selected randomly and in the new case a mobile worker is selected according to his ETA. Also in the old case all mobile workers have to return to the inventory after delivering each order as in the new case only if necessary because they carry mobile stocks with them.

Looking at the results of the old situation (scenario 5) versus the new situation (scenario 1), we see that with the new dispatching policy, the mean response time decreases from 51.64 minutes to 44.46 minutes, without increasing the workload of mobile workers. Moreover, the utilization of mobile workers spreads more evenly on average of 12.8% (with a std. deviation of 1.73) in new situation, comparing to the largely different utilization (with a mean of 14.7%, and std. deviation of 11.19) in the old situation. Nevertheless, the results are very much related to the specification of mobile stocks of each mobile worker, and can be influenced by the changing order behavior of customers, as evidenced in scenario 3 and 4.

The experiment results of different scenarios reveal that with the new dispatching policy, it is possible to achieve an enhanced service performance. It also implies that to achieve an optimized result, there are needs for decision making on the setting of relevant factors and their configuration (e.g. mobile stock). As we have illustrated, simulation is an effective means to support such a decision making. Through running the simulation model, we are able to support decision makers using appropriate data obtained from the results of the run. We wrap up our discussion next.

5.3.3 Discussion

To ensure the agility of the suite, the SOA approach was considered to be very useful since it enabled us to change the simulation settings and model specifications in an easy way. Relating the simulation suite to the principles of SOA we state that the service provider in SOA can be equated to each of the individual building blocks since they perform the task of service provision; the service consumer can be equated to the modeler in the BEaMS project since this is the actor that consumes the services exposed by the service provider; and the service registry can be equated to the information contained in the Model document, World file, Dispatching Policy, etc. Based on this way of thinking, we were able to achieve the implementation of the suite using principles drawn from SOA, to develop loosely coupled building blocks that can be easily changed without affecting the performance of the suite.

To illustrate the flexibility of the building blocks of the simulation suite, we used two cases taken from different contexts, each with different dispatching issues. The differences meant that we had to use the building blocks to model some of the business processes based on the context. For example, in the G4 case, we used the building blocks to simulate a patrolling processes enabled by a new dispatching policy, within the context of *SequentialTripTravel* mode and *NonProductServing* mode for each of the mobile guards. In the KCI case, we used the building blocks to simulate a delivery process enabled by a new dispatching policy, within the context of a combination of the *RoundTripTravel* and the *SequentialTripTravel* mode, with the *ProductServing* mode for each deliverer.

We illustrated that it was possible to analyze quantitatively the new dispatching processes enabled by mobile workforce solutions, and we believe that without the simulation suite this would be difficult. Using the suite, it is possible to identify excess capacity and reassign the field workers based on the statistical feedback received from the simulation model. The suite enables a flexible approach to simulating the dispatching processes and this helps decision maker to estimate pro-actively the mobile solution capacity. With dynamic dispatching policies such as the ones implemented in the simulation suite, awareness among decision makers can be raised regarding the potential impacts on the productivity of the mobile workforce. Moreover, experiments such as changing the trip mode, e.g. round travel or sequential travel, can be performed, with the aim of gaining insights into the possible procedures in the context of mobile solutions.

It is necessary to point out that some potentially important business processes were not implemented in the suite, for example the sorting order process with its priority. To overcome this limitation, an extension of the `Order` building block (refer to section 5.3) needs to be made, followed by slight adjustments in other building blocks. Moreover, as an indicator for future work that may be carried out on the suite, the building blocks can be extended to provide functionality for performing cost calculations for the route traveled by a mobile worker. In the current implementation, the only parameter that matters is the shortest route taken to get to a customer location.

Business analysts and mobile service designers who mostly have the task of analyzing and designing business processes do not have adequate knowledge of either programming or dynamic modeling. They need a suite that easier to use. The library developed does not need the modeler to go through the building blocks. To develop a simulation model, only instances need to be instantiated by providing the argument required. This avoids the need of deep programming, and less experience of simulation is required by developing simulation model using the library than developing simulation model from scratch. Thus, it is expected that to use the suite will be easier and with minimum effort required for developing a simulation model.

Our belief is that many BEaMS projects are not isolated. Although the suite was not specifically developed to capture every possible business process simulation issue, we believe that it has the potential to reach the functionality needed to simulate situations with similar requirements as those that were illustrated using the cases. The simulation suite can be extended to explore relevant design issues such as team planning, personnel allocation, resource capacity and location etc.

5.4 Conclusions

In this chapter, we discussed the development of building blocks to facilitate the dynamic modeling of business processes in the domain of mobile field services. We demonstrated that our building blocks can be generated from the existing service processes and that they can be used to tackle the complexity found in the domain. We preferred to use building blocks because they prevent us from wasting time by developing a simulation model from scratch each time we require one in a BEaMS project. We implemented the building blocks to simulate mobile workforce allocation and dispatch policies, and illustrated the application using two cases. The model was constructed by instantiating the building blocks library. We focused on the building blocks for modeling and simulating dispatching and scheduling process enabled by mobile services support. The use of building blocks to model the business process in the illustration cases proved that building blocks are usable for the development of a simulation suite for BEaMS.

We make a further reflection on the functional requirements of the suite that were presented in chapter 4 (section 4.5.2).

Req.4-1. The suite should support the demonstration of key changes due to the proposed mobile solutions on business processes.

Using the suite, we were able to demonstrate the key changes that would occur in the business processes if the new dispatching and allocation policies were applied to a mobile workforce. Through the illustration cases, we were able to confirm that this requirement was fulfilled, using the dispatching processes as examples of typical business process that require attention in a BEaMS project.

Req.4-2. The suite should support quantitative analysis of key system performance indicators through statistical features.
Using the parameters provided, e.g. processing time, delivery time, etc., the decision makers will be able to experience the dynamics of a new business process and understand whether implementing the new process would be feasible. We were also able to provide key performance indicators that can be used by decision makers to analyze the new business processes and that can also be used to diagnose "what-if" situations.

Req.4-3. The suite should support the evaluation of results from different experiments through an animation feature.
Using the animation feature of the simulation suite, we were able to visualize the execution of some business processes. For example, using the route map that was developed to visualize the delivery processes in the KCI illustration case, it is possible to see the movement of each of the mobile workers relative to the customer sites. Overall, the functional requirements of the suite were met, and we argue that the suite can be presented to the experts to determine the value it adds to their BEaMS work.

As was discussed in section 5.1, field service operations usually do not respond to conventional productivity-improvement programs, because managers have difficulty coordinating the work of employees they cannot see on the job. With the simulation suite, we were able to provide the mangers with a map and visualization capabilities that can be used to show the locations of each of the employees in the field. The illustration cases also enabled us to assess the usefulness of the building blocks in BEaMS projects. The simulation model provided performance indicators for the business process in terms of response time to order and utilization of the mobile workers. We are convinced that managers can use the outputs obtained from running the simulation model to justify their decisions regarding mobile solution design. The evaluation of the suite and the studio as a whole is presented in chapter 6.

Chapter 6 Evaluation of the support studio

In this chapter we describe the evaluation procedures carried out on the simulation-based support studio in its application to BEaMS. The evaluation for application of the support studio was carried out using expert interviews with the purpose of evaluating the value of the studio in BEaMS and in reflection of the results that had been obtained in the illustration discussed in chapter 5. In addition, we used Delft University of Technology students that were taking the Mobile Service Systems Engineering masters course to evaluate the simulation-based studio since they were more knowledgeable in the simulation field than the experts who were used in the evaluation. The choice for using the students was based on the premise that they could provide some feedback on the use of simulation in the engineering of services. The evaluation was aimed at assessing whether the studio adds value to the process of BEaMS approach.

6.1 Design of evaluation

6.1.1 The purpose of evaluation

We presented the simulation-based support studio in the previous chapter, and discussed some of the tests that were carried out. We now discuss the evaluation that was carried out based on the aspects of usability, usefulness, and usage. The aim of carrying out the evaluation was to address the fourth research question: *What is the added value of using the support studio in the process of BEaMS?*

The evaluation was based on the requirements for BEaMS effectiveness as presented in chapter 4, section 4.1, also see table 6.1 below.

Studio design requirements	Aimed BEaMS effectiveness
Req. 1 The studio should be able to increase the awareness of the potential impacts on organization, business processes, and individuals, and trigger a proactive approach for BEaMS.	Process-awareness
Req. 2 The studio should be able to facilitate effective means of communication among stakeholders, e.g. process/service designers, management and the mobile workers.	Consensus
Req. 3 The studio should be able to enable process/service designers to focus on the relevant design issues and guide their efforts on context specific issues.	Focused design process
Req. 4 The studio should be able to support service designers in addressing the creative process of conceiving potential services by providing the dynamic models of the targeted business process.	What-if modeling

Table 6.1 Studio design requirements and aimed effectiveness for BEaMS

6.1.2 Measurement constructs

Measurement constructs for testing the studio were based on the concept of the 3 U's taken from (Keen & Sol, 2007), which states that the *usefulness* aspect addresses the value that a studio adds to the decision-making process in the development of mobile services, the *usability* aspect addresses the mesh between people, processes, and technology and the easy of interaction and collaboration it enables, while the *usage* aspect addresses how the suite is embedded in the process while using it to develop mobile services. We used the concept of the "3Us" to examine the studio based on the requirements presented in table 6.1.

In order to measure application of the studio on each of the U's we find it necessary to improve the understanding of the key theoretical constructs for general measures used in the information systems (IS) field. Two well-known measurement theories in the IS field were chosen for this purpose: the Technology Acceptance Model (TAM) (Davis, 1989) and Usability Engineering (Nielsen, 1994).

The TAM model as presented by Davis (1989) states that users are likely to use a system when the system is perceived as useful and perceived as easy to use (see figure 6.1). In the TAM model, *perceived usefulness* is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance", and *perceived ease of use* as "the degree to which the person believes that using a particular system would be free of effort" (Davis, 1989). This effort consists of physical effort, mental effort, and ease of learning the system.

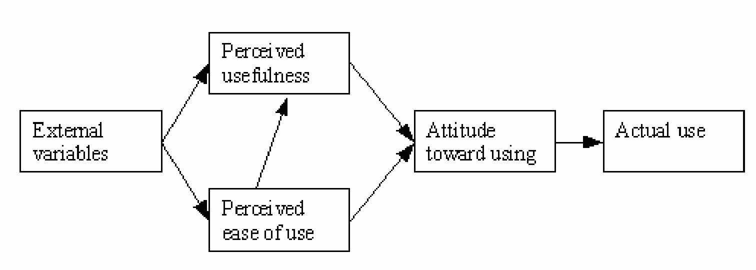

Figure 6.1 TAM model based on Davis (1989)

A different approach to evaluating usefulness and usability is presented by Nielsen (1994). A part of the model developed by Nielsen (1994) is shown in figure 6.2. According to Nielsen, a system's practical acceptance is a result of the combination of characteristics of the system, i.e. usefulness, cost, compatibility, reliability and other factors. Where *usefulness* is related to how suitable a system is in achieving a certain goal. This concept is a combination of the *utility* and the *usability* of a system. *Utility* describes whether appropriate functionality is at hand and *usability* is defined as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. Nielsen (1992) defines five main usability parameters: learnability, efficiency of use once the system has been learned, ability for infrequent users to return to the system without having to learn how to use it again, frequency and seriousness of user errors, and subjective user satisfaction.

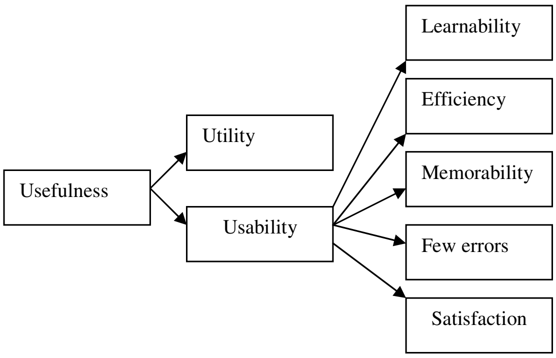

Figure 6.2 System acceptability (based on Nielsen, 1993)

Although the model presented by Nielsen (1994) originally focuses on usability engineering, and the TAM model (Davis, 1989) originally focuses on the adoption of technology in organization settings, we argue that if a support studio is to be considered as being useful, it is more likely to be accepted and used by the target users. By translating the concept of *usefulness* (in Nielsen's model), we argue that a decision maker should consider the studio as having utility and being usable. In other words, the decision maker is likely to consider a support studio useful when it fits his or her needs and tasks and when the studio is easy to use. For the purpose of this research we interpreted our understanding of the 3U's with regard to the two models above.

- *Usefulness* of the studio can be derived based on the "perceived usefulness" in the TAM model, and the "utility" concept in the model of Nielsen.
- *Usability* of the studio can be derived based on the "perceived ease of use" in the TAM model, and the "usability" concept in the model of Nielsen.
- *Usage* of the studio can be derived from the "actual use" in the TAM model.

The focus of this research is on the evaluation of perceived "usefulness" and perceived "usage". We consider usability to be less important at this stage, because the focus of our design was not on the user interaction with the suite, but more on the functionality provided by the suite (also see chapter 4, section 4.5). These measurement constructs provided us with the theoretical foundation on which to measure the performance of the studio. A questionnaire was designed for measurement purposes based on these constructs. The questions were divided into four groups, each corresponding to a requirement as presented in table 6.1. In each of the four groups, questions were different since they were designed for measuring different "U". The format of the questionnaire is shown in table 6.2. A complete discussion of the questionnaire is presented in section 6.2.

Studio design requirement X (X=1, 2, 3 and 4)	
Usefulness	Question 1 …. Question L
Usability	Question L+1 … Question M
Usage	Question M+1 … Question N

Table 6.2 Format of questionnaire

6.1.3 Evaluation method

We considered expert interviews to be the preferred research instrument to evaluate the support studio. This research instrument was chosen because we needed to get an independent evaluation of the support studio from experts not involved in the development of the support studio. We argue that an evaluation by objective and knowledgeable experts improves ones own insight into issues related to usefulness of the support studio, and such an evaluation can help ultimately helps to build a convincing argument for the studio's usefulness.

The objective of the expert interview was to evaluate whether the support studio was useful for assisting the process of improving the effectiveness of BEaMS. The focus of the expert interviews was on the methodology of the support studio, and not on the software library (i.e. suite). The results of the expert interviews were expected to provoke discussions on the theoretical and practical barriers to the usefulness of the support studio in business engineering.

In addition to the expert evaluation, we also organized a testing session with a group of master students taking the course Mobile Service System Engineering at Delft University of Technology. The group evaluation with students was intended to obtain extra measures for the questionnaire items designed for expert evaluation. In particular, in this large testing session, more focus was given to evaluating the *usefulness* of the simulation suite for designing mobile services. The feedback was expected to work as a supplement to the expert interview results, considering that the participants in the expert interviews might have had limited time to feel the simulation suite fully during an interview session.

We realized that the questions designed for the expert interviews could not be employed among the students directly because the students had different expertise and background in comparison with the experts. Therefore, we adapted the questions to a level that was suitable for students to answer and to ensure the reliability of the obtained results from the student evaluation session. In order to follow the central line of evaluation design, we discuss the results of the student session in subsection 6.2.3.

6.1.4 Structure of expert interview approach

The target group for the expert interviews was carefully chosen from the following organizations: LogicaCMG, Atos Consulting, IBM, Intel, Capco, Mobile Result, and TNO. These organizations were chosen because they are largely involved in mobile service design projects, and the support studio is designed to be relevant in solving real-life BEaMS problems. The chosen experts consisted of decision makers, consultants, practitioners and researchers who had experience with or knowledge of the application domain, i.e. decision making in enterprise mobility, mobile services design, business engineering; and the solution domain, i.e. business process modeling, simulation, and decision support systems. Most of the experts were subject matter professionals who had worked in the field for many years, with different roles, such as business analysts, mobile service designers or project managers, as defined in chapter 4. Some of the experts were also interviewed during the inductive case studies. Their input during the inductive case studies helped us to formulate the design requirements for the support studio, and they were thus regarded as being capable of forming an acceptable scientific opinion on the support studio. We argue that using such an expert group would ensure the robustness of our evaluation and the consistency of the designed research.

The experts were asked formally to participate in the evaluation of the studio. Each of the experts was provided with a short explanation of the objectives of the interview, which was sent to them 4 weeks in advance to allow them adequate time to prepare and to familiarize themselves with the research work. A total of 8 expert interview sessions was held during the evaluation period running from December 2006 to February 2007. Each session was given in the form of peer interviews (one expert per time). We invited the expert(s) for a two hour long interview session. The researcher conducted all the interview sessions, in which all the discussions were recorded for further analysis. In addition, the researcher took notes during the interview sessions. To ensure the commonality of each session, a reusable session agenda was used as follows:

<u>Agenda item 1</u>

1:00 pm Introduction
1:10 pm Background information on the research.

<u>Agenda item 2</u>

1:20 pm Studio walk through with a presentation

<u>Agenda item 3</u>

1:40 pm An application of the support suit in the testing case/address the requests from the expert
2:10 pm Discussion on the challenges and the potential use of the studio with the expert

<u>Agenda item 4</u>

2:30 pm Questionnaire and open discussion
3:00 pm End

The structure of the expert interview sessions consists of four steps, which were prepared with a view on reusability. In the first step of the interview session, a short introduction to the research problem was given. The problem of BEaMS was explained to the experts using the testing cases presented in chapter 5 and literature references. In this first step, the experts were given some time to reflect their view on the research problem. The research questions, scope, and research methodology were also explained during this introductory step.

Afterwards, the argumentation behind the choices made to address the problem was explained. The choices made for using decision enhancement studio, the use of simulation as a method of inquiry to get insight into the dynamics of mobile business processes, and the use of recipes to guide the process-oriented design approach, were made explicit to the experts. The introductory session lasted for 10 minutes.

In the second step, the support studio was presented to the experts using a structured walk-through. The goal and structure of the support studio, the approach/methodology used in the support studio, the libraries relevant for the modeling and simulation process were presented. The experts were taken through the whole concept of a studio and given an explanation of the functionality of the software libraries contained in the suite.

In the third step, the application of the support studio to improve BEaMS was presented based on the two illustration cases presented in chapter 5. Based on the expert's interest, we choose the illustration case[12] to present and explained how the support studio could support the analysis of a what-if scenario in that particular case. Next, we facilitated the experts in a quick and direct practice of the suite for a selected issue, which was about designing a mobility-enhanced business process in a given context, e.g. a real time dispatching process enabled by location based services. In so doing, the experts were expected to form more profound opinions on the usefulness of the support studio.

In the final step, the experts were asked to answer the evaluation questions presented to them in the form of a questionnaire. The experts were expected to provide further explanations to their argumentation behind the evaluation.

6.2 Interview Results

6.2.1 Measurement scale

The questions are formulated as statements that forced the interviewees to make their opinions explicit. In this study, we used a 5-point Likert scale to measure perceived attitudes of the experts by providing a range of responses to a given statement. The interviewees could answer a question based on five-point scale ranging through strongly disagree (1), disagree (2), neutral (3), agree (4) to strongly agree (5). The statements were formulated in both positive and negative way. For the negative statements, we inferred from low scores that the interviewees are positive about an item we were measuring, while for the positive statements, we inferred from a high score that the experts were positive about a particular aspect of the studio. The relative difference between answers is hence reflected in the difference in the number.

Blaikie (2005) observes that "it has become common practice to assume that Likert-type categories constitute interval-level measurement." Jamieson (2004) stresses that the response categories in Likert scales have rank order, but the intervals between values cannot be presumed equal, although "researchers frequently assume that they are". As a result, Likert scales fall within the ordinal level of measurement.

The legitimacy of assuming an interval scale for Likert-type categories is an important issue, because the appropriate descriptive and inferential statistics differ from ordinal and interval variables (Cohen et al 2000), and if the wrong statistical technique is used, the researcher increases the chance of coming to the wrong conclusion about the significance of his research (Jamieson 2004).

In this research, we follow on Jamieson (2004), and concur that Likert scales fall within the ordinal level of measurement. When treated as ordinal data, Likert responses can be analyzed using non-parametric tests, such as the Mann-Whitney test, the Wilcoxon signed-rank test, and the Kruskal-Wallis test. It is worthwhile to note that the mean and standard deviation may not be appropriate for analyzing ordinal data.

6.2.2 Non-parametric statistical method

We used two different groups of subjects to carry out the evaluation of the suite, using the questionnaires presented in 6.2.3 and 6.2.4. Non-parametric statistical methods were used to analyze the findings since the subjects involved in the study were few and not chosen randomly

[12] The illustration cases are chosen from chapter 5, where case1 (G4 in the domain of security and patrol), and case 2 (KCI in the domain of transport and delivery) are described in detail. A set of issues for expert to experience the simulation suite are also based on the contents in chapter 5.

from a large population. Our goal was to find the representative power of the results, and not necessarily the statistical significance, following on the work of (de Vreede, 1995; Yin, 1989). We decided not to use parametric statistical analysis techniques because our aim was not to explore the relationship between groups (e.g. Pearson correlation), nor was it to explore the differences between groups (e.g. T-test). In line with our evaluation purpose (see 6.1.1), we decided to evaluate the answers of the two groups of subjects (experts and students) separately. Since each question item was designed independently and corresponding to a single construct, we decided not to focus on the strength of the relationship between the question items but instead focused on the individual characteristics of the suite being measured.

For each of the main parametric techniques there is a non-parametric counterpart. "Non-parametric techniques are useful when you have very small samples, and when your data do not meet the stringent assumptions of the parametric techniques" (Pallant, 2005). This was applicable to our research which had a small sample size, and hence the decision to use non-parametric techniques.

Our main focus in the analysis phase was to gain indications about the directions of the answers. For each observation, we were only interested in one characteristic – whether or not the observation exceeded the standard. We could therefore treat this characteristic as a binomial distribution, with regard to the underlying distribution of each observation (Conover 1980). We followed the work of Janssen (2000) and chose to use the quantile test (Conover, 1980; Siegel & Castellan, 1988) as a non-parametric statistical technique for data analysis in this study.

A *quantile* test is used to determine if answers are significantly positive, i.e. agree (4) or strongly agree (5), by comparing the scores of the interviews with the theoretical probability that the same number of positive answers is obtained by taking a random sample. If this probability is smaller than the confidence level α, the set of answers is considered to be significantly positive. The theoretical probability of a particular number of positive answers, given a sample size, can be calculated using the binomial distribution (Conover, 1980). A disadvantage of this test is that nuances in the answers are neglected, because no distinction between an answer of 4 (agree) and 5 (strongly agree) is made.

As a conclusion, we argue that the application of non-parametric tests in this research was considered to be feasible and suitable, given that non-parametric tests can be applied to constructs for which it is impossible to obtain quantitative measures (descriptive studies), as well as to small sample sizes. It is worthwhile to note that non-parametric techniques, however, do not solve the problem of potential dependency between the answers of the interviewees. Consequently the results should be interpreted carefully.

6.2.3 Inferring the results of expert interview

As we argued when designing the questionnaire, we were interested in a valuation of the following parameters, which were central to the performance of our support studio.

- *Process awareness*
- *Consensus*
- *Focused design process*
- *What-if modeling*

We used descriptive statistics to analyze the basic features of the data of interview results. With descriptive statistics we simply describe what the data is, and what the data shows. We conclude with summaries about the measures. When inferring the results, we only present the most critical analysis summaries in this chapter. This is because if we present too much detail, we may not be able to follow the central line of the results.

The answers regarding each category are shown in tables 6.3, 6.4, 6.5, and 6.6. In these tables, the numbers represent the frequency of responses given to each statement on the Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), *X* is used to represent the mean, *s* is used to represent the standard deviation, and *pos* is used to indicate the number of positive answers, i.e. 4 and 5 (for negative statements 1 and 2 are counted instead.) The prefix "-" is used to indicate that the result is of a negative statement. *Sign.* is used to indicate if the answer is significantly positive given a two-sided *quantile* test, sample size of n, a probability of a positive answer of p=0.5 and a confidence level of α=0.05. While the mean and standard deviation are calculated and presented in the tables, they are not used in the analysis. The analysis is based only on the frequency of responses represented by the value of *pos*, which is used as the indicator of perceived attitudes among the interviewees. In this research n=8, Sign shows "yes" when |Pos|>=6, otherwise it is "no" (according to Table A3, (Conover, 1980)).

Perceived usefulness (question 1-5)
The answers presented in table 6.3 indicate that most participants valued the simulation suite, as it helped them to gain insights into the business processes targeted in the case |Pos| = 5). This was especially so for issues regarding actors involved, their activities, and the information flow among them (question 1 & 2). Two experts who gave the low mark to question 2 commented that the process of using the suite to construct a simulation model will give them more insight, but not the suite itself. In their opinion, the questions were not formulated in a clear way. They both agreed that if the questions were reformulated to read "using the suite helped me…", then they would be able to give a positive answer to the statement. The interviewees found that the landscaping guidelines were easy to understand, and they agreed that the guidelines were of vital importance to improve the process awareness (question 4 & 5). However, they felt that the guidelines could be further specified to be easily followed in practice (question 3). For example, one expert commented that he missed the constraints and contexts to apply the guideline "L3", which, he thought, would be very important to decide its actual application.

Perceived usage (question 6-8)
The answers presented in table 6.3 show a positive feedback. Significantly, this means that the experts were optimistic with the future use of the guidelines in practice (question 7), with a high |Pos| = 7 and a significant difference. The only different voice said "if I present the landscaping guidelines to my team, they can be easily taken for granted, being more a matter of common sense rather than of systematic thought and rationality. But I don't think this situation is what 'accepted' means, which to me should be as same as 'implemented'; obviously the guidelines may not be easy to implement due to many other issues." The other interviewees held mixed views about the improvement of process awareness among stakeholders (question 8), with |Pos| = 4. One of the interviewees commented that the results would depend on stakeholders' willingness to cooperate and their actual involvement in the design process". Another interviewee remarked that stakeholders were more interested in the final results, and that the process awareness was hard to create, or even may not necessary for them.

Questions	1	2	3	4	5	x	s	Pos	Sign.
1 The suite helped me better understand the general operational processes targeted in the project.			3	4	1	3.75	0.71	5	n
2 The suite helped me better understand the actors involved, their activities, and the information flow among them.		2	2	1	3	3.63	1.30	4	n
3 The guidelines are too high level and hard to be implemented.		5	2	1		2.50	0.76	-5	n
4 The guidelines are easy to understand and practical.			1	6	1	3.75	0.46	7	y
5 The studio is not useful to improve the process awareness.	4	3		1		1.75	1.04	-7	y
6 I am concerned with its acceptance in a real project.	1	5	2			2.13	0.64	-6	y
7 I am optimistic with the future use of these guidelines in practice.		1		6	1	3.88	0.83	7	y
8 I don't think the process awareness among the stakeholders can be improved with the studio.	1	3	2	1	1	2.75	1.28	-4	n

Table 6.3 Answers regarding process awareness

Perceived usefulness (question 9-13)

The results presented in table 6.4 indicate that the models were viewed as a useful means for the interviewees to communicate with their colleagues, and therefore most interviewees were optimistic about the introduction of the suite to their project teams (question 9 & 10), with |Pos| = 8. One expert was very impressed with the functions of the suite that eased communications between designers with different perspectives regarding process models. This interviewee immediately showed interest to invite the researcher to introduce the suite to his colleagues. The initiation guidelines gained a large recognition from the interviewees. All the interviewees agreed that the setup and control of a design team was absolutely an important issue to tackle based on their experiences in many projects. They felt that the initiation guidelines were very necessary and would be useful to improve the situation in the very early phase of a design project (question 12 & 13), both with |Pos| = 7. The results show that only half of interviewees thought that the initiation guidelines were formulated in a way that was easy to understand (question 11). The remaining half suggested an improvement in the way we presented the guidelines. For example, one expert commented that the guideline "start with creating awareness: a list of method" should be corrected to read "start with creating possibilities of common vocabulary, trust, and commitment". This was considered by this expert as being far more important than awareness.

Perceived usage (question 14-16)

An interesting finding presented in table 6.4 is that the participants had positive responses, though not significant, regarding their commitment to use the initiation guidelines themselves (question 15 & 16), with |Pos| being less than 6. However, they had slight concerns on the acceptance of the guidelines in a real project (question 14). A representative explanation was like this, "to make the imitation guidelines work within a project team, all team members have to understand and accept the guidelines collectively; the learning curve is unavoidable to some of us, and I cannot be sure that everybody would like these guidelines as I do".

Questions	1	2	3	4	5	x	s	Pos	Sign.
9 Models provide a useful means for me to share the perspective with my colleagues.				5	3	4.38	0.52	8	y
10 I think it is useful to introduce the suite to my project team.			2	6		3.75	0.46	6	y
11 The *initiation* guidelines are easy to understand.		1	2	4	1	3.63	0.92	5	n
12 I think the *initiation* guidelines are usable (or necessary) in practice.		1		7		3.75	0.71	7	y
13 Overall, I think the *initiation* guidelines are useful.		1		7		3.75	0.71	7	y
14 I am concerned with its acceptance in a real project.	1	2	2	3		2.88	1.13	-3	n
15 I will follow the guidelines to improve the communication processes in the project.		1	2	5		3.50	0.76	5	n
16 I will not use the initiation guidelines.		5	2	1		2.50	0.76	-5	n

Table 6.4 Answers regarding consensus

Perceived Usefulness (question 17-22)

The results presented in table 6.5 show that the experts were satisfied with the simulation of the scenario in the given case, and most of them felt positive regarding their requests on simulation of an alternative scenario during the discussion (question 17 and 18) with |Pos| = 7 and |Pos| = 5 respectively. The case that was used to illustrate the application of the suite in each evaluation session was regarded as appropriate and representative (question 19) with |Pos| = 7. More than half of experts said that they had been involved in similar projects in terms of project settings, client interests and requests, and the technology solutions. Viewing the capability of the suite, the experts believed that the way in which the suite was used in the testing case could be applied to many other projects to solve similar issues (question 20). The recipe, which outlines the steps around the use of the simulation suite, was also evaluated by the interviewees. The results obtain indicate that the information provided in the recipe was easy to understand (question 21). The experts found the recipe to be very useful in guiding a focused simulation based design approach (question 22).

Perceived Usage (question 23-25)

Due to time constrains and our focus on the simulation based approach, we did not present and evaluate other recipes during the session. All the discussion was around the simulation based recipe. As presented in table 6.5, half of the experts showed strong interest in knowing more about this recipe (question 23). The question about their willingness to follow the recipe in their design process was answered significantly positive (question 24). However, this indication seems not to mean that the experts had no concerns on the acceptance of the guidelines in a real project (question 25). The experts who showed concerns commented: “It is worthwhile to consider the recipe from a methodological point of view; only in such a way, I would say they are ‘accepted’. Obviously, it is not so easy to reach the real ‘acceptance’”

Questions	1	2	3	4	5	x	s	Pos	Sign.
17 The scenario in my mind is well simulated by the suite.			1	5	2	4.13	0.64	7	y
18 The suite can provide an alternative solution (model) on my request during the session.			3	2	3	4.00	0.93	5	n
19 The illustrated case is relevant to design issues of mobile services.			1	3	4	4.38	0.74	7	y
20 I experienced similar issues, and I thought the suite can be used to solve these issues			2	4	2	4.00	0.76	6	y
21 I found the recipe is easy to follow.				5	3	4.38	0.52	8	y
22 Overall, I found the recipe is useful.			2	4	2	4.00	0.76	6	y
23 I am interested to know more about the recipe.		1	3	3	1	3.50	0.93	4	n
24 I will follow the recipe in the design process.			2	6		3.75	0.46	6	y
25 I am concerned with its acceptance in a real project.		3	3	2		2.88	0.83	-3	n

Table 6.5 Answers regarding focused design process

Perceived usefulness (question 26-30)

The question about the value of using the suite in the testing case was answered significantly positive (question 26) with |Pos| = 7. Viewing the capability of the suite, the interviewees agreed that there were lots of possible ways to use the suite (question 27). When asked whether the suite provided some functions that they could not get through other tools, the experts did not answer significantly positive (question 28). Five of the ten interviewees chose the neutral option. One expert explained that "the suite to me is quite new and I don't know whether there exist similar tools, and how to make a comparison; so I would rather be conservative to answer this question due to my limited knowledge scope." The application and presentation of dynamic models was highly favored by the interviewees (question 29) with |Pos| = 8. The answers were significantly positive regarding the perceived usefulness of the simulation suite (question 30) with |Pos| = 7.

Perceived usability (question 31-36)

The results presented in table 6.6 show that the building blocks were easily understandable, and the process of constructing a simulation model using the building blocks was easy to follow to most of the interviewees (question 31 & 32). Only one of the experts felt that it was difficult to capture how the simulation model was constructed by using the building blocks. Some experts commented that the instructions of how to use the suite in the given case culd be further improved (question 33), for example, taking into account the audience's knowledge on simulation and programming. The answers regarding the clarity of the simulation result were varied (question 34), three gave negative answers, two chose neutral, and three answered positively. Among those giving negative answers, some expected a more lively visualization of the result while some expected a more direct indication on the cost and benefit because to them, this would be the ultimate result to influence decision making. The experts were significantly satisfied with the fact that their questions about the simulation model of the case were well addressed during the interview (question 35).

Perceived usage (question 37-38)

The question "I will be interested in using the suite in the design process" was answered significantly positively (question 37). All experts indicated a positive value. Most of the interviewees were not concerned with the acceptance of the suite in a real project (question 38). They commented that the suite was something off shelf, and the value was visible and clear. They thought the suite was easier to be accepted than the guidelines which were somehow intangible. The two interviewees who showed their concerns commented, "I am convinced its value, but I am concerned with the extra time and cost needed to deploy the suite. In practice, it has to be clear that the benefit is greater than the cost; moreover, the project manager has to approve such a budget for use of the suite. This might be difficult given that many projects run under a limited budget and time scope."

Questions	1	2	3	4	5	x	s	Pos	Sign.
26 The use of the suite in the case is of value.			1	3	4	4.38	0.74	7	y
27 I can see a lot of possible ways to use the suite.			1	3	4	4.38	0.74	7	y
28 The suite provides some functions that I can not get through other tools.			5	4		3.38	0.52	4	n
29 Overall I like the dynamic models.				5	3	4.38	0.52	8	y
30 Overall, I found the simulation suite is useful.			1	5	2	4.13	0.64	7	y
31 The building blocks are too conceptual and I cannot understand where/how to use.	1	6	1			2.00	0.53	-7	y
32 I can follow the simulation model construction.		1		7		3.75	0.71	7	y
33 The instructions about how to use the suite during the session are understandable			4	3	1	3.63	0.74	5	n
34 The simulation result is hard to understand.		3	2	2	1	3.13	1.13	-3	n
35 My questions on the simulation model are well explained during the session.			1	5	2	4.13	0.64	7	y
36 I am concerned with the time needed to construct the simulation model.	1	2	4	1		2.63	0.92	-3	n
37 I will be interested in using the suite in the design process.				8	0	4.00	0.00	8	y
38I am concerned with the acceptance in real projects.		4	2	1	1	3.13	0.99	-4	n

Table 6.6 Answers regarding modeling use

6.2.4 Inferring the results of the students

Table 6.7 shows the results obtained during the demonstration session with the students. As mentioned in 6.1.3, our focus in the student evaluation session was on the usefulness of the studio, and especially the suite. In line with this focus, the attention here was given to inferring the answers regarding "modeling use" and "overall usefulness of suite".

The students agreed that the simulation based studio helped them to better understand the general operational processes targeted in the mobile workforce service system (question 1). They strongly agreed that the studio could guide the designers to better understand the actors involved, their activities, and the information flows among them (question 2). The questions regarding "consensus" were all answered significantly positively (question 3, 4, 5). With their experiences of designing mobile services in teams based on a class assignment, the students were optimistic that the studio could be a useful means to share views and to ease the communications among designers and stakeholders. The results show that the students did not think that the studio based approach was easy to follow (question 6), neither did the students think that they experienced similar problems where the recipe and the suite can be applied (question 7). This may not be a surprising result because the mobile services designed by the students were quite diverse, and most of them had little similarity with the testing case. Nevertheless, it was more important to evaluate the simulation concept as part of the design approach. Thus, it was interesting to see that the question "the use of simulation is a good way to illustrate the potential value of the service" was valued significantly positively (question 8).

The questions regarding the functionality and the value of the suite were answered significantly positively (question 9 & 10). The students had no problem in following the construction of the simulation model in the case, and they found the result easy to follow (question 12 & 14). From the nine students who participated in the evaluation, four of them thought that the building blocks were not conceptual at all, and they could understand where and how to use them (question 11). Four of the nine students chose a positive answer when asked whether they felt comfortable using simulation in their design project (question 13). The question that “I can see a lot of possible ways to use the simulation suite” was not answered significantly positively (question 16). In general, the students found the suite to be useful (question 17).

We also asked the students a number of questions to reflect on the overall usefulness of the studio based approach as a mobile service design methodology. The results indicated that the students valued the added value of the studio significantly positively (question 18 & 22).

Questions	5	4	3	2	1	Mean (n=9)	Stdv. (n=9)	Pos	Sign.
Process awareness									
1The simulation based studio helped me better understand the general operational processes targeted in the mobile workforce service system.		5	3	1		3.44	0.73	5	n
2 The simulation based studio will guide the designers to better understand the actors involved, their activities, and the information flow among them.	3	3	2			4.00	0.87	6	y
Consensus									
3 Models provide a useful means for me to share the perspective with my team member (co-designers).	2	5	1	1		3.89	0.93	7	y
4 I think the dynamic models are helpful to ease the communications within our team.	3	5		1		4.11	0.93	8	y
5 An appropriate use of simulation helps to gain insights and share views among stakeholders during the service design process	4	3	1	1		4.11	1.05	7	y
Focused design process									
6 I find the studio based approach is easy to follow.		3	3	2		3.22	0.83	3	n
7 I experienced similar issues in my design project, and I think the recipe and the suite can be used to solve these issues		2	5	2		3.00	0.71	2	n
8 The use of simulation is a good way to illustrate the potential value of the service.	3	5	1			4.22	0.67	8	y
Modeling use									
9 The functions of the simulation suite are interesting.	3	4	2			4.11	0.78	7	y
10 The use of the simulation suite in the case is of value.		6	3			3.67	0.50	6	y
11 The building blocks are too conceptual and I cannot understand where/how to use.			5	4		2.44	0.53	-4	n
12 I can follow the simulation model construction.	1	6	2			3.89	0.60	7	y
13 I feel comfortable to use simulation in my design process.	1	3	3	2		3.33	1.00	4	n
14 The simulation result is hard to understand.		4	2	3		2.22	0.83	-5	n
15 I am interested to know how to apply the suite in my project.	3	1	3	2		3.56	1.24	4	n
16 I can see a lot of possible ways to use the simulation suite.	1	2	5	1		3.33	0.87	3	n
17 Overall, I find the simulation suite is useful.	2	4	3			3.89	0.78	6	y
Overall usefulness of the studio									
18 I do not see any advantage in using the studio.				6	2	1.67	0.50	-8	y
19 I would prefer to achieve the same task without the studio.			5	3	1	2.44	0.73	-4	n
20 The studio has functions that I need in designing my service system.	1	3	2	3		3.22	1.09	4	n
21 I would like to learn more about the studio.		5	3	1		3.44	0.73	5	n
22 In general, I see the added value in using the studio to perform service design.	1	6	2			3.89	0.60	7	y

Table 6.7 Answers of student evaluation session

6.3 Analysis of findings

In general, all experts and students thought that the questions were formulated clearly and understandably, as indicated by the responses presented in tables 6.3 – 6.7. They all felt comfortable with the presentation and interview questions. One expert remarked: "the chosen case is very typical and representative. It is in such organizations where mobile worker involved, mobile solutions are changing their business. The case is also illustrative. With concrete issues in the case, it is clear to me that how the recipe is followed, and where the suite is used."

We collected the common questions from the two groups, and presented the results in table 6.8. The results are a supplement to the main findings, and their importance is that they indicate the level of consistency between the responses given by the experts and the students. Further, the importance of including these results is that they enabled us to determine the value of aspects of the studio that the experts did not have knowledge to respond to the statements, for example, for the simulation-related aspects of the studio.

	Students (n=9)				Experts (n=8)			
questions	mean	stdv	Pos	Sign.	mean	stdv	Pos	Sign.
a. The simulation based studio helped me better understand the general operational processes targeted in the mobile workforce service system.	3.44	0.73	5	n	3.75	0.71	5	n
b. The simulation based studio will guide the designers to better understand the actors involved, their activities, and the information flow among them.	4	0.87	6	y	3.75	1.28	5	n
c. Models provide a useful means for me to share the perspective with my team member (co-designers).	3.89	0.93	7	y	4.38	0.52	8	y
d. I find the studio based approach is easy to follow.	3.22	0.83	3	n	4.63	0.52	8	y
e. I experienced similar issues in my design project, and I think the recipe and the suite can be used to solve these issues	3	0.71	2	n	4	0.76	6	y
f. The use of the simulation suite in the case is of value.	3.67	0.5	6	y	4.38	0.74	7	y
g. The building blocks are too conceptual and I cannot understand where/how to use.	2.44	0.53	-4	n	2.00	0.53	-7	y
h. I can see a lot of possible ways to use the simulation suite.	3.33	0.87	3	n	4.38	0.74	7	y
i. Overall, I find the simulation suite is useful.	3.89	0.78	6	y	4.25	0.71	7	y

Table 6.8 Common questions answered by students and experts

As shown in table 6.8, answers to question a, c, f, and i were consistent in valuation (e.g. significantly positive or not significantly positive) in both groups. However, the valuation of the remaining questions was different. We notice that especially for question d, e, g, and h, the answers from two groups varied considerably. We argue that this difference can be explained by taking into account the background of the interviewees. For example, for question “I can see a lot of possible ways to use the simulation suite”, the experts answered much more positively than the students maybe due to their broader views and experiences in the field. In this study, we think the answers from the experts were more valid, and we chose these answers as primary evidence for the analysis as follows.

What-if modeling
The simulation suite was considered to be the most innovative and impressive element in the studio by most of the experts. Employing simulation models to investigate alternative business processes can support service designers to gain more insight into business processes. In that sense, we can conclude that process awareness among designers of a BEaMS project can be improved using the simulation-based studio since it provides the capacity to perform “what-if” modeling.

The type of input data can be deterministic, for example whether the average value is used as direct input to the simulation, or a stochastic distribution that best models the data. During the evaluation, the interviewees seemed to be more interested in the outputs of the simulation model than in the accuracy of the data input, as it enabled them to explore various possible scenarios in the mobile services business environment. Based on this we can conclude that:

- *uncertainties and dynamics can be better understood and analyzed by using the simulation based studio.*

Mobility value proposition
Uninterrupted connectivity has been the primary criterion of BEaMS projects; rigorous decision support for creating value added services is still not gaining enough attention. The studio is a useful approach to filling in the gap. Service designers need specific guidelines provided in the studio to have a balanced and holistic perspective: business processes, decision support, operational efficiency, and resource utilization, etc. One expert remarked that “Simply speaking, the studio allows us to link business value proposition (e.g. operational efficiency) with optional mobile solutions in a simulation environment.”

Another expert had the following comment: “in order to justify the cost/benefit of implementing a mobile solution and help design the solution, a tool is always needed to estimate its benefit in terms of reduced operation cost and improved efficiency. The simulation suite was considered to be a good choice in this case. It provided more dynamics and a more lively presentation than the one we used currently, say Excel.” Based on this we conclude that:

- *the studio is useful in the course of exploration and analysis of translating mobile solution strategies into a business operation arrangement.*

Effectiveness
One expert commented on the effectiveness of the recipe: “I see that the goal-driven way of working is dominant in many mobile design projects. We start with the development of a vision for the business processes of the organization. However, we do little research on analyzing the differences between this target vision and the current situation. This is because we think creativity would be hindered by paying too much attention to the current situation.” … “It is interesting to see that the recipe stresses a start with detailed analysis of current processes, and then looking for gaps between current and potential performance.” … “The difference between two approaches seems in the extent to which the current and future processes need to be modeled and analyzed. Moreover, I think the recipe is good in the sense that it stresses the evaluation of alternatives by simulation before implementation, which we don’t do much in our goal-driven way of working. I think this step brings the core value of the recipe to my knowledge, and it is definitely something I can take away today, of course together with its supporting suite.”

Another expert commented on the effectiveness of the suite: “To me, the suite provides a simulation metamodel for field services with an integrated mobile solution. With a discrete event simulation model, it is possible to evaluate resource allocation and dispatching strategies for mobile workers performing on-site tasks. Therefore, I think the suite is most effective for engineering mobility in field service industry.” Based on this discussion, we can conclude that:

- *the studio emphasizes a rational approach for BEaMS, which may result in more effectiveness than the ones used in current practices.*

Added value

Many experts were very curious about the term “studio” before the session. Some of them expected a physical environment like a laboratory. After we presented the studio concept to them and demonstrated the use of the studio with the testing case, they began to like it and thought it was more interesting than what they expected.

One senior consultant from LogicaCMG commented, “I feel that the content of the studio can always be further extended. It can be used as a repository of relevant guidelines, methods, and tools. So, new elements can always be added. I think it is especially important for the purpose of knowledge management in consulting firms. It seems a means to make the common sense or knowledge explicit. I like the concept of studio based design approach, and I believe it can enforce a more effective way of working, and importantly it can improve the reusability of knowledge and resources.”

Many experts who play the role of consultant commented that: “I think the suite is very useful to help me sell our mobile solution to our clients… because I can prove the potential value of the mobile solution for the client organization with the suite. It can strengthen our consultancy regarding to our client’s inquiry. So in that sense it can be a good ‘sales tool’, which is a great added value to me.” According to another expert, “many mobile projects stay in analysis or design phase for many years just because the real value is not explicit to the management. A commitment (or an approval) for real implementation is all we work for. The suite may help to convince the management with the result.” Based on this discussion, we can conclude that:

- *the added value of the suite to consulting firms can be summarized as the provision of a thorough means to show the potential value of mobile solutions; it can offer quantitative evidence to convince the client organizations.*

Flexibility

The experts were impressed with flexibility of the suite with the ability of changing the dispatching mode in the simulation models in line with different mobile solutions, e.g. with location-based service, or without location-based service, in setting values for experiment parameters, in adjusting simulation treatment, in loading maps for animation, etc. During the sessions, they were very curious about how to experiment with the different scenarios through simple configurations, so that corresponding results in terms of response time, and productivity of mobile works were available. They were also convinced that constructing a simulation model with building blocks was more flexible and easier.

One expert commented, “I like most the flexibility the suite provides to estimate the value of other business process decisions such as alternative mobile worker dispatching strategies.” Another expert had the following remark: “a mobile solution for field service concerns a complex system consisting of several sub systems that interact with each other. So I like the way the suite is architected -module based, or in your word, building block based. I think this architecture allows the suite to be used in a more flexible way. For instance, the suite can be used to assess the effect of an alternative scheduling system on field productivity; and to assess alternative workforce management policies as a result of time registration application in many mobile projects." Based on this discussion, we can conclude that:

- *the flexibility of the suite enables the stakeholders to perform 'what-if' analysis and is important in developing mobile solutions since the complexity of the various alternative process designs can be modeled.*

Limitations

It is hard to evaluate the effectiveness of the simulation-based support studio as a whole without considering side issues that usually occur and have effect in practice. Although the experts valued the studio as a rational approach, they also pointed out that there were many irrational factors in the design projects of mobile solutions, such as political considerations, regulatory reasons, and security issues. One expert explained with an example: "in one project, the LBS is requested by the client organization though we, as consultants, doubt any value of it for their operation process. However, the management just decided to have it without any reasons. So in such cases, situation might be in opposition to the assumptions of a studio based approach."

The interviewees were curious about how the suite could be available to them. Four of the experts showed strong interest in having the suite for their own use. When asked "do you think you can manage to use it", only one expert was quite confident. The rest of the experts suggested that it would be ideal to have a more user friendly interface so that they could be able to use the suite themselves without facilitation.

Regarding distribution of the studio, the experts had the following considerations. Firstly, it might be hard to sell it directly to a consulting firm because the firm needs an investment on human capitals. Secondly, using the suite needs expertise in simulation, so it requires a learning curve just as any other tool. Training and supporting it will be difficult. Thirdly, it might be a solution to rent the suite as a service. However, to make this business model work, some references of the proven value are critical.

One interviewee who had expertise in business process management commented "the landscaping and initiation guidelines are a little bit confusing to me. They are more like guidelines for project management. I do not know how they are different from those mentioned in Prince2 or Six-sigma. Choosing a paradigm, like hard or soft systems thinking, sometimes is dependent on a number of factors, e.g. the kind of people involved in the project. I do not think it is very possible or practical to impose a guideline. It is something that can be recognized and keep in your mind."

We also observed that some experts thought the suite was more useful to the design team than to the stakeholders. They stressed that it was a good tool for exploration in the early stages of a project; to support analysis, but not to decide on a solution. They agreed that it was also possible to come back to the suite for more detailed analysis when key issues in a project became clearer.

6.4 Conclusions

In order to increase an organizations' process awareness and insight into the further business processes of mobile workforces, we developed a simulation based support studio. The core component of the studio is the simulation suite that can be used to address many relevant issues in mobile service design, such as workforce utilization, process optimization, scheduling and dispatching capacity, and scenario experiment.

With the support studio, the designers can become more aware of the business processes involved in defining the mobile service. The approach of designing a mobile service together with other stakeholders helps initiate successful results. An appropriate use of simulation suite helps to gain insight and shared views among the stakeholders. The interviewees were satisfied with the studio-based approach as applied in the testing cases, considering their experience with other design approaches. They agreed that the recipes were helpful in engineering a mobile solution more effectively. Based on the evaluation that were carried out on the studio and the evaluation, we can conclude that:

- *the studio was perceived to be useful as a means for structuring a BEaMS project.*

The overall conclusion was based on the qualitative observations that were drawn from the quantitative analysis of the responses to the interview questions. Through the evaluation and the testing exercise, we were able to learn that it is very important to ensure that the values of all the stakeholders in a BEaMS project are taken into consideration. The simulation suite provides the stakeholders with a tool that can be used to design a mobile service solution and perform 'what-if' analysis that enables them to explore new ways of determining the effects of mobile business processes.

We also state that the use of the suite is not only limited to the type of business processes illustrated in the testing cases, nor is it limited to improving or optimizing existing business processes. The suite, as an extendable simulation library, can be further applied to simulate relevant business processes that enables us to demonstrate the opportunities arising from the value of ever changing mobile capabilities.

Chapter 7 Epilogue

We started this research by observing and identifying the current problems and challenges faced in the research field of business engineering and mobile services (BEaMS). The objective of the research was to develop a simulation based studio that can be used to improve the effectiveness of business engineering and mobile services in organizations. The exploratory case studies we carried out for the NS and the RWS Inspection enriched our understanding of the problems faced in BEaMS projects and enabled us to identify the main issues to be considered when carrying out such projects. Based on the issues identified through the case studies, we formulated a set of requirements and constructs for the support studio, and developed a suite for mobile field services simulation using the building blocks concept. To illustrate how the suite can be used to simulate business process in BEaMS projects, we used two case studies in which mobile workforces are an integral part of the business process. The concept of a support studio in BEaMS was evaluated using expert interviews. In this chapter, we reflect upon our research, we discuss our research findings in section 7.1, our research approach in section 7.2 and provide some directions for further research in section 7.3.

7.1 Research findings

In this section, we present the research findings by discussing and answering our research questions. The central research objective was to develop a simulation based studio that can be used to improve the effectiveness of business engineering and mobile services (BEaMS) in organizations. In order to develop such a studio, we formulated several key research questions in chapter one. Below we discuss the answers to the research questions.

7.1.1 Research question one

The first research question was formulated as: *What are the current and emerging issues in practice of BEaMS?* This research question was intended to help us get a detailed understanding of the problems, issues, and challenges of business engineering and mobile workforce solutions.

This research question was answered in chapter two. We used exploratory case study as a major means to explore and gain a better understanding of the topic. Following Yin (1989; 2003), we used the case study method, and chose the “Railpockets connection” project and the “RWS inspection” project as the two cases to enable us to focus the work and to enrich our understanding of the issues to consider when carrying out BEaMS projects. We cooperated with the project teams directly involved in these projects as they could provide us with insight into the relevant issues that we wanted to explore.

To address the question, we identified two aspects that were relevant, which formed the units of our analysis for both case studies (see figure 2.1):

- current and emerging issues of mobile workforce solutions in organizations
- current design approaches for new business processes and the mobile workforce solutions

For the first unit of analysis, we formulated and used an analysis framework based on three level division of business engineering (Smith & McKeen, 1993), which allowed us to take an in depth overview of the issues of mobile workforce solutions in organizations. In particular, we paid attention to the issues related to workforce management, knowledge management, organizational structure, business process automation, business process alignment, and mobile workforce capability, task and acceptance.

For the second unit of analysis, we used the “ways of” analytical framework based on Sol (1990), which is structured in terms of a way of thinking, a way of working, a way of modeling and a way of controlling. We chose this framework to guide our analysis, because the achievement of business engineering and mobile workforce solutions needs to follow a certain design approach, and the “ways of” framework proves useful for gaining insight into the relevant design issues.

The two units of analysis were applied in each of the two case studies. The issues identified from the cases regarding the first unit of analysis were presented in table 2.3 and table 2.5 in chapter 2. The findings regarding the second unit of analysis were discussed in 2.2.3 and 2.3.3. Some of the main findings in the practice of business engineering and mobile workforce solutions can be attributed to the following issues:

- technologies supporting mobility make an important contribution for business process engineering. The identification of opportunities for “mobility” is increasingly becoming a core issue for many companies.
- the barriers for the adoption of mobile solutions in organizations are not to be found in the technology challenges, like network integration, device management, routine support and maintenance. Many packages and tools are available to help people deploy enterprise mobility in the current market.
- the biggest challenge for many projects is not to find mature mobile technologies (see above), but to fit the mobile technology into their business operations. The real challenge is how to instantiate mature mobile technologies and form a business solution that is suitable for the organizational environment.
- organizations need to be notified of the impacts of mobile workforce solutions on their organizational business environments. It is also important to help employees find creative ways of coping with changes caused by mobile workforce solutions.
- mobile workforce projects have in the past taken a long time in the design phase and have been hard to roll out. As time passes, technology moves on; good documentation of the current situation is important; flexibility and scalability of a solution are needed.
- designing mobile workforce solutions is often conducted in a context of multi-actor systems. It is important to stimulate and support the participation of all the actors involved.
- the solution provided to improve the effectiveness of BEaMS in organizations should support the analysis of mobile business processes; redesign of the identified process; specification of the mobile element as required by the new processes; validation of the profitability of the change; and implementation of the change.
- “what-if” models should be provided at the point of need. Through the use of the “what-if” models it should be possible to research integration of a mobile solution with existing business processes and to provide measurement functions in terms of efficiency, and productivity.

These issues make it challenging to improve the effectiveness of BEaMS in organizations since the business analysts are not in a position to determine the impacts of the solutions they offer. A new approach is required that gives directions on how the business processes may be reengineered in the context of mobile workforce solutions. The new approach should present views based on existing research into business engineering best practices. Ineffective support for the design of BEaMS projects will lead to slow uptake of mobile workforce solutions, which will lead to long lead times in service provision by the mobile workers.

7.1.2 Research question two

As discussed in chapter one, we consider simulation to be an effective method of inquiry for business engineering in organizations. Towards this end, we formulated the second research question as: *What are appropriate concepts to constitute the simulation based support environment?* This research questions was intended to help us to gain a sound theoretical background on the important concepts in the domain of BEaMS and to help us to define the relevant principles for our support environment.

In chapter three, we discussed a number of concepts and focused on the studio as a means of facilitating the decision support process for developing a simulation based support environment. In particular, we reviewed the literature from three angles, i.e. mobile services in organizations, business engineering and decision support.

The first angle: mobile services in organization.

We first discussed the categories of mobile services, and narrowed down our focus on business to employee (B2E) mobile services, which is alternatively called mobile workforce solution. We briefly explained the typical application areas where mobile workforce solutions can be expected to show benefits, i.e. mobile sales-force automation, mobile supply-chain management, mobile access to email, personal information management, mobile tracing and tracking, and mobile dispatching and scheduling.

In order to make a clear and comprehensive understanding of mobile workforce's work and supporting mobile services, we studied further the nature of mobile work support, looking at four fundamental aspects: mobile workers, mobile tasks, mobile context, and mobile technology. Knowing who mobile workers are helps us to identify the right target for mobile services. It is also important to consider the characteristics of various mobile workers in order to tailor mobile services to meet their specific needs. Mobile tasks require mobile workers to be present on the site physically and usually the tasks need to be finished within a specific time period. This makes the location/time dependency a very important characteristic of mobile tasks (Balasubramanian et al., 2002). However, the constraints of spatial/temporal context restrict the workers with different possibilities for configuring and reconfiguring their relationships with others, different possibilities for performing actions, different possibilities for habitual action through which meaning and identity could be attached to place, and different possibilities for temporal structure configuration (Brown & O'hara, 2003). The fast growing mobile technologies enable the development of various mobile services to support mobile workers and help them to accomplish their tasks in a mobile context.

The main characteristic of m-services is their ability to provide coordination, control and decision support within the business process under the restriction of spatial and temporal limitations. The introduction of mobile services into the work context may affect the spatial and temporal dimensions of mobile workers' tasks and hence the whole business processes. Thus it is crucial to focus our perspective on process changes when designing mobile workforce solutions. Designing such solutions involves complex activities and involves many actors in the design process. We look at designing mobile workforce solutions as a problem solving process due to the fact that several possible courses of action can be identified to improve the problem situation, and that the new mobile workforce environment contains factors that affect the possible courses of action that designers can take. To form a problem solving based design approach, it is worthwhile to adopt a business engineering perspective.

The second angle: business engineering

A plethora of BE methodologies have been identified in the literature. Kettinger et al. (1998) conducted an empirical review of existing methodologies for business process change, and point to the lack of a comprehensive, scientifically grounded design methodology to structure, guide, and improve organizational design efforts. Analysis and redesign of business processes are the focus of many BE methodologies. The common central questions to be answered by BE projects are, for example, how to design or redesign an effective and efficient business process in practice, how to determine the performance of a business process, or how to allocate resources in an operational business process.

Meel and Sol (1996) provide a thorough introduction to the use of simulation for the integrated modeling and analysis of business process and information systems. They advocate the development of computer-based dynamic models of business processes as a crucial mechanism to support the process of business engineering. Hansen (1994) also advocates the appropriateness of simulation for Business Engineering, arguing that "an engineering approach to process reengineering that incorporates modeling and simulation is necessary". Business process simulation research is built on the field of simulation in general. Many researchers in the simulation field proposed a set of high level steps to guide a simulation study (Banks, 1998b; Cohen et al., 1972). The most common steps are: conceptualization, specification, verification & validation, and experimentation& solution finding. An important aspect of business process simulation is its ability to capture the dynamic (i.e. time-dependent) behavior of a process. There are two aspects of dynamic systems that need to be addressed (Greasley, 2003):

- Variability. Most business systems contain variability in both the demand on the process (e.g. order arrival) and in duration of processes (e.g. service times) within the system. The use of deterministic (e.g. average) values will provide some indication of performance, but simulation permits the incorporation of statistical distributions and thus provides an indication of both the range and variability of the performance of the process.
- Interdependence. Most systems contain a number of decision points that affect the overall performance of the system. The simulation technique can incorporate statistical distributions to model the likely decision options taken. Also the "knock-on" affect of many interdependent decisions over time can be assessed using the simulation's ability to show system behavior over a time period.

As a result, the business engineering perspective, built upon problem-solving thinking, can be viewed as a starting point towards a systematic design approach for mobile services in organizations. In particular, business process simulation might provide a solution to gain insights into the dynamic aspects of process changes enabled by mobile services, i.e. the spatial and temporal changes of a mobile context and the related changes of the entire business process.

The third angle: decision support

As we learnt from the case studies in chapter two, designing mobile solutions for business customers is a complex undertaking because it requires different organizations, including their multiple actors, to balance different working needs. For instance, on the one hand, the inadequate knowledge of managers who do not have a clear idea of how to use the opportunities presented by mobile technology is one major factor inhibiting mobile business (Lehmann et al., 2004); one the other hand, many predictions about the impact of mobile services in business are over-hyped by consulting bodies (Kadyte, 2005). Within such a context, we see that a new approach to BEaMS requires embedded facilitation and support for decision making regarding relevant mobile workforce design issues.

Decision support is not just about software, models and tools: decision support is about making decisions following a method of inquiry. According to Sol (1982), simulation is an effective method of inquiry for organizational decision making. Sol (1982) states a simulation inquiry system is able to address the following decision making requirements:

- the possibility to emphasize the activity of conceptualization by presenting freedom for the construction of a "base model"
- the possibility to construct a model system in view of the availability and attainability of data, and to place it in an experimental frame
- the possibility to generate alternative solutions and analyze these in comparison with the initial specification

Built on the decision support theories and practices, Keen and Sol (2007) introduce the concept of a "studio" to refer to a support environment through which the decision enhancement process is achieved. The goal of using a studio is to help decision makers rehearse the future by building their confidence through direct use of appropriate simulation models, information systems, analytic methods and interactive tools in their own decision making processes. Recipes and suites are two key elements that constitute a studio. The studio concept, and its underlying way of thinking, was chosen as a basis for developing the support environment in this research.

Mobile services in organization are considered as an enabler of business engineering, and a business engineering approach is a way with which to attain effective mobile services in organization. The concept of decision enhancement services provides a solution that facilitates a balanced integral approach based on these two views.

7.1.3 Research question three

After understanding the challenges and relevant concepts of engineering mobile workforce solutions in organizations, the third issue that was addressed in the research was to look at ways to improve the BEaMS effort. Therefore, the third research question was formulated as: *What are recipes and what are contents of the suite?* This research question directed the researcher to develop a support studio. The construct of the support studio consists of landscaping guidelines, initiating guidelines, recipes and suites. This construct is in line with the methodology defined by Sol (1990) using the "four ways" framework: way of thinking, way of controlling, way of working and way of modeling.

The fulfillment of the studio was carried out in chapter 4 and chapter 5. In particular, we discussed how the recipes are derived based on the requirements of the support studio and reflecting on the generic landscaping and initiating guidelines in chapter 4. We present a set of recipes for carrying out BEaMS effectively and provide justification for the need of a simulation suite. We described how the supporting simulation suite is conceptualized and developed in chapter 5. We briefly describe the studio-based approach for BEaMS as follows.

Landscaping and initiating guidelines

These guidelines reflect our recommendations on the way of thinking and the way of controlling for a BEaMS project. We follow Sol (1990), and claim that the functionality of the support studio depends on the underlying philosophy or way of thinking used to look at the problem situation and information systems under consideration. In the landscaping and initiating guidelines, we delineate the view on BEaMS projects, and provide methodological principles on which the recipes and the suite are based. These methodological principles are rooted in our belief in, and understanding on, systems thinking, multi-actor perspective, and business engineering approach (see guidelines 1-8 in chapter 4, section 4.2 and 4.3).

Recipes

The recipes of the support studio are the result of integrating the directive guidelines for landscaping and initiating. Within the recipes, we provided the sequence of steps to be followed to achieve a BEaMS effort. The recipes are operational and reinforce a way of working.

The recipes are structured in line with our assumption of the three phases of a BEaMS project (see figure 4.4). The first phase is concerned with performing a business requirements study, creating a strategy with which to formulate the BEaMS project, and forming the team to carry out the project. The second phase is concerned with conducting a thorough business requirements study for the BEaMS project with a focus on process design. The third phase is concerned with developing the mobile solution and deploying it in the organization. Given the scope of this research, we limited the focus of the recipes to the first two phases of a BEaMS project. For the activities of the first phase, we provide recipes on how the initial business requirements study is carried out, how to formulate a BEaMS project, and how to establish the project team and kick off the project. For the activities of the second phased, we provide recipes for carrying out a business analysis with a focus on process and service design issues. The targeted users of the recipes are mainly the business analysts and mobile service designers of a BEaMS project, as we defined in figure 4.5. The details of the recipes were described in section 4.4. In particular, we emphasize the essential steps to follow to carry out a thorough analysis in phase two (see subsection 4.4.4.), in which we argued for the use of dynamic modeling approach to identify and simulate the business processes that a mobile solution could be used to support. These steps include identifying existing core business processes, assessing potential for improvement by the opportunities of mobile services, mapping alternative business processes based on the results of mobile services, analyzing alternative business processes by simulation, and deducting general conditions and requirements for services and systems design.

These steps are of core interest to enable a dynamic view on process analysis, and to ensure a process driven approach for mobile service design. To facilitate the implementation of these steps, we identified the need to provide a supporting simulation suite. We further elaborated three functionality requirements that have to be met by the suite, i.e. support the demonstration of key changes of the proposed mobile solutions on business processes (Req4-1), support quantitative analysis of key system performance indicators through statistics features (Req4-2), and support the evaluation of different experiment results through animation feature (Req4-3).

Suite

The suite reflects our recommendations on the way of modeling. According to Keen and Sol (2007), suites are used to provide the technology to support recipe application. We considered the use of a simulation suite for deployment within the studio as the best way for modeling the dynamics inherent in a mobile workforce related business process. The suite was defined as a domain specific simulation library, and more details are presented in chapter 5.

The implementation of the classes in the simulation library uses the concept of building blocks. The building blocks are independent of each other, each representing a specific element of field service processes. The change or replacement of one building block will not affect the functionality of the other building blocks. This ensures the flexibility and extendibility of the simulation library with regards to its contents. Moreover, the simulation library was developed using java programming language, which ensures the platform independence of the simulation library.

We chose a discrete event simulation-based approach (i.e. dynamic modeling approach) to form our view on object oriented modeling and simulation. The building blocks were conceptualized and specified based on our study on the domain of field service processes. Within the domain, we limited the scope of the library to the simulation of the dynamics of new dispatching processes enabled by location based services, since dispatching processes pose the most common problems as perceived from the literature and actual practice. The basic building blocks conceptualized are Customer, DispatchCenter, Order, CustomerCenter, MobileWorker, and RoadMap. The exogenous inputs, experiment variables, and performance measures that needed to be included in the library were identified, formulated and specified based on literature, empirical data, and assumptions made in this research.

The implementation of the building blocks was rooted in the Distributed Simulation Object Library (DSOL). DSOL is a Java-based open source simulation language that supports all activities but conceptualization in a simulation study (Jacobs et al., 2002). We used the DEVSSimulator, a DEVS formalism based simulator, provided by DSOL (Jacobs et al., 2002), to serve as the simulation engine in our suite. The suite was constructed according to the class diagram presented in figure 5.6. As we can see from the class diagram the suite consists of a static world containing the instance of the DEVSSimulator, instances of all mentioned building blocks, and classes, enumerators and interfaces to support the interaction between the building blocks, and the animation and GUI services.

The suite provided a Java library of simulation building blocks which can be used to model and simulate mobile field service processes, especially for dispatching and scheduling processes. It contains objects representing mobile workers, customers, orders, product types, roads, and dispatch centers. A complete model can be specified using the XML input files, which are parsed to instantiate the required objects, their initial conditions, and the experiment configuration.

We illustrated the use of the suite in two cases in section 5.3. Using the suite, we were able to demonstrate the key changes that would occur in the business processes if the new dispatching and allocation policies were applied to a mobile workforce. Using the parameters provided, e.g. processing time, delivery time, etc., the decision makers can experience and gain insight in the dynamics of a new business process. Using the animation feature of the simulation suite, we were able to visualize the execution of some business processes. Overall, the functional requirements of the suite were met, and we argue that the suite can be presented to the experts to determine the value it adds to their BEaMS work.

7.1.4 Research question four

The fourth research question was formulated as: What is the added value of using the support studio in the process of BEaMS? This research question was addressed in chapter 6, in which we present the results of the evaluation of the studio. We carried out an evaluation of the support studio mainly using expert interviews with a reflection on the studio constructs presented in chapter 4, and the results that had been obtained in the illustration cases discussed in chapter 5.

Based on the exploratory case and a literature review, four requirements were formulated for the support studio to satisfy so that it could be used to improve the BEaMS effectiveness. The first requirement (Req1) stresses that the studio should provide guidelines that enable decision makers to increase awareness of mobile workforce solutions on organizations, and trigger a proactive approach for BEaMS. We presented a set of guidelines that enable the decision makers to create a systems thinking and conduct the BEaMS project using a business process engineering approach. The second requirement (Req2) stresses the need for the support studio to facilitate effective communication between stakeholders involved in the BEaMS project. We proposed that to facilitate the decision makers we need to regard the changing roles and capabilities of the various types of mobile solutions providers as an important issue, because it helps to clarify roles and actors of a

BEaMS project. The third requirement (Req3) stresses on enabling service designers to focus their attention on relevant issues during the design of a mobile solution. Towards this end, we presented the recipes for use within the studio. The recipes center on the design of mobile workforce solutions in a multi-actor situation, with the aim of supporting each of the actors in performing their mobile service design activities. The fourth requirement (Req4) stresses the need to capture effective "as-is" models of the business processes targeted by the BEaMS project, and to support the decision makers in performing "what-if" analysis of the proposed mobile solution. To address the requirement, we proposed the use of a simulation suite and discussed the underlying reasons in support of the simulation suite. With an on-screen visualization of the process simulation model, important performance indicators such as orders quantities, response time to each order, and workforce utilization were highlighted at every moment of simulation time. The application of the suite was also illustrated using two cases.

The expert evaluation was based on the four requirements, supplemented with aspects on the three dimensions of usability, usefulness, and usage. The experts agreed that with the support studio, decision makers can become more aware of the business processes involved in defining the mobile service. The approach of designing a mobile service together with other stakeholders helps initiate successful results. An appropriate use of simulation suite helps to gain insight and shared views among the stakeholders. The interviewees were satisfied with the studio-based approach as applied in the illustration cases, considering their experience with other design approaches. They agreed that the recipes were helpful in engineering a mobile solution more effectively.

Even though some experts who mostly have the task of analyzing and designing business processes do not have adequate knowledge of either programming or dynamic modeling, they were confident with the usability of the suite. To develop a simulation model using the suite, only instances need to be created by providing the argument required, which avoids the need of deep programming and less experience of simulation is required. Nevertheless, as indicated in section 6.3, the experts raised a few usability issues that will help with the adoption of the support studio in practice. The experts did not find any theoretical barrier to using the support studio to improve the effectiveness of BEaMS.

Based on the research we carried out, it is our strong conviction that the support studio is potentially useful, and usable to improve the effectiveness of organization's approach for BEaMS. The support studio can be used to help in the engineering of mobile workforce solutions and to perform 'what-if' analysis that enables us to explore new ways of determining the effects of mobile services on business processes. The contribution of the studio-based approach is significant for the types of field service organizations and mobile solution consulting parties that are dedicated to embracing BEaMS in operation. However, considering that we used only two illustration cases and expert interviews to evaluate the usefulness and usability of the support studio we cannot generalize the results to mean that the studio can be used in any BEaMS approach.

7.2 Research design

In the previous section, we discussed the output of the research. In this section, we reflect back on the research methodology that was used. To address the research questions discussed in the previous section, we used a research methodology that had three dimensions: a research philosophy, a research strategy and research instruments.

The research philosophy adopted in this research was a mixture of the interpretivist and positivist philosophies. The choice of the research perspective was based on the research field and research purpose. In chapter 1, section 1.4 we stated that the objective of the research was to develop a simulation based support environment that can be used to improve the effectiveness of business engineering and mobile services (BEaMS) in organizations. Our research can be categorized as an interdisciplinary combination of organizations research and information systems research. The purpose of the research calls for strong engagement with the world of organizations, and therefore we chose to use the interpretive philosophy, which focuses on studying phenomena in their natural environment.

The way we address the objective was to construct a support studio, and obtained knowledge about its use in supporting BEaMS projects by studying how it can be used in the context of two illustration cases. To evaluate our research result, we chose to use the positivist philosophy, and through this philosophy we were able to study the use of the studio within the user environment to determine the value added.

With regard to the research strategy, we advocated the use of the inductive-hypothetic model cycle developed by Sol (1982), which is considered to be most appropriate for ill-structured problems. The engineering of business processes enabled by mobile services is an ill-structured problem, and the aim of this research can be seen as providing support that can be used to solve this problem. According to Meel (1994) and Sol (1982), the main benefits of an inductive-hypothetic strategy are that it emphasizes the specification and testing of premises in an inductive way; it opens up possibilities for a problem specification using an interdisciplinary approach; it enables the generation of various alternatives for the solution of the problem; and it permits learning regarding the analysis and synthesis as independent activities. These benefits made the inductive-hypothetic model cycle very useful as a research strategy for BEaMS, which is a new and emerging research field. Based on a set of requirements, we were able to design the support studio by first identifying the business issues and then evaluating the usefulness and usability of the support studio in illustration cases and by using expert interviews.

We used several research instruments to implement our research strategy. Although the inductive-hypothetic research strategy can be used to describe clearly the order and interdependence of the research steps, it gives no indication of how to conduct the various steps. In the initial phase of the research, exploratory case studies were used to enable us to get a grip on the actual issues in organizations with regard to business engineering and mobile services. These exploratory case studies also enabled us to understand the significance of simulation in BEaMS projects. In the later stages of the research, we used a laboratory experiment to test the support studio among a group of students. The advantage of this laboratory experiment is that it helped us to focus on a set of evaluation parameters and to determine the value of the support studio in BEaMS projects. As discussed in section 1.5, combining different research instruments is preferred to achieve a comprehensive test and evaluation. Towards this end, we used expert interviews to evaluate the value added by using the support studio. The experts were not involved in the development of the support studio, and were interviewed to get an independent evaluation of the support studio. This evaluation was based on the demonstration of the simulation suite using the two illustration case studies. The experts were business analysts who have wide experience and are regularly involved in mobile workforce related projects, and were therefore regarded as being capable of forming an accepted opinion in the field of BEaMS. The objective evaluation by the experts enabled us to obtain further information regarding the usefulness and usability of the support studio. We conclude that the choice of the inductive-hypothetic approach was appropriate for addressing the research objective of the study.

7.3 Further research

During the research process, a number of issues were addressed and a number of other new issues arose. In this section, we discussed issues that need to be investigated further.

In chapter five we used two case studies to demonstrate the use of the simulation suite. There are two reasons for choosing this approach: first, we needed to focus on the illustration of the functionality of the suite without external interference; secondly, there were some difficulties in finding opportunities to conduct action research on the application of the suite and the recipes, as the studio based approach for BEaMS was a novel idea at the time of the research, yet the relevant organizations were not willing to spend a lot of resources on studying the effect of the new solutions. Even though the expert evaluation revealed that the suite was usable and useful in the illustration cases, an investigation should be done to assess its usability and usefulness in real BEaMS projects with mobile field service design issues and complex process redesign issues. Such action research should also involve real stakeholders using the support studio to improve the effectiveness of their approach to BEaMS. This leads us to make the following two recommendations.

Recommendation 1: test the usability and usefulness of the support studio in real BEaMS projects using action research.

Recommendation 2: test the usability and usefulness of the support studio by involving decision makers who are likely to use the studio directly in their BEaMS practice.

As we indicated in chapter 1, BEaMS is a new and promising interdisciplinary research domain that lacks methodological support which would ensure a minimum level of rigor, facilitate structuring, monitoring, and assist in codifying experience and ideas. To tackle this challenge, we adopted a simulation based inquiry approach in this research. In particular, we used discrete-event simulation (referring to it as dynamic modeling (Meel & Sol, 1996)) as the intervention approach and developed a support studio. The simulation suite as it currently stands supports the modeling of dispatching and allocation business process. These are important processes for any mobile workforce, but there are several other processes that form a complete business process. Towards this end, we make the following recommendation:

Recommendation 3: further develop the suite with expanded functionalities that cover a complete business function.

In this research, we developed a support studio for BEaMS. The theoretical basis for the requirements that were identified comes from the work of Keen and Sol (2007), who state that effective decision enhancement rests on the three U's: *Usefulness, Usability,* and *Usage*. The *usefulness* of a decision support studio addresses the value it adds to the decision making process. The *usability* of a decision support studio deals with the mesh between people, processes and technology. The *usage* dimension deals with how the support studio is embedded in the decision process. The three U's are equally important for effective decision enhancement (Keen and Sol, 2007). Even though all the three U's are equally important for effective decision support, in this research we only considered the usefulness and usability when evaluating the support studio. This was mainly because the exploratory case studies did not help us to identify and extract usage related requirements for the studio, and the cases that were used to test the simulation suite did not enable us to come up with actual user experiences in using the suite. Requirements related to usage can be obtained by understanding the way the actual users of the suite would use it in real life situations. This leads us to make the following recommendation:

Recommendation 4: identify "usage" related requirements from practice to complete the set of requirements for decision enhancement to improve the effectiveness of BEaMS.

The support studio provides a good way to resolve decision making issues and enforce problem solving cycles in practice. The design of studio-based approaches in different domains or subjects can be carried out to determine the value added by the studio-based approach to the decision making process in business engineering. A more profound studio should be generalizable in its application, something that is particularly valuable for consulting firms. This leads us to make the following recommendation:

Recommendation 5: carry out research into the generalizability issues of the studio so that different types of business engineering projects can be carried out without the need to develop a new studio each time.

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Appendices

Appendix 1 Case Study Interview Protocol

This case study protocol covers two sections:

- field procedures, i.e. presentation of credentials, access to the case study "sites", general sources of information, an procedural reminders
- case study questions

A. Data collection procedures:

A1. names of sites to be visited, including contact persons

A2. data collection plan, i.e. cover the calendar period for the site visits, the amount of time to be used for each visit, and the level of effort to do each case study

A3. expected preparation prior to site visits, i.e. identifies specific documents to be reviewed and where they can be accessed

B. Open questions:

B1. Impacts of current mobile workforce solutions on business processes

- What is the design for evaluating the impacts of the project and who is doing the evaluation?
- What are your insights in the impacts of "mobile workforce solutions" on organizations?
- What is the feedback from the clients regarding the potential impact of "mobile workforce solutions"?

B2. Organizations' experience of how the business processes are engineered by mobile workforce solutions

- What is your analysis and design approach for the new business processes?
- What are the methods used in this approach?
- Which aspects have you considered in this approach, ,i.e. workflow, information flow, organizational structure, culture impact, HR management?

B3. Current and potential problems in engineering new business processes enabled by mobile workforce solutions:

- What part of the evaluation of the solution has been implemented?
- What are the measures being used, and what outcomes have been identified to date?

C. Supplemental questions for B:

- Has the business process change been evaluated before examining the mobile technology?
- To what extent, business process change has been analyzed, e.g. scenario, process diagram, simulation, etc.?
- Who were involved in this analysis process, e.g. business analyst, IT professional?
- Has the design of new business process been shared with other personnel, e.g. mobile workforce, administrative manager, operation manager, etc.?
- Has the design of new business process been used for other purpose, e.g. education/training of workforce, for instance to show why a higher responsibility is expected from him in the new business process?
- Have you ever experienced these situations: hard to implement the solution because one segment of the new process does not have an overview of the others; solution does not work effectively as expected; problems arise in some other departments; workforce does not accept the application and refuses to use?

Appendix 2 List of Methods for Phase One of a BEaMS Project

In line with our discussion in subsection 4.4.1, it is important for decision makers to follow a set of activities that simultaneously assess organizations' internal and external business environments and develop their awareness of strategic mobile business directions. The following methods can be used as the first steps of a mobile solution project, as shown in table 1.

Most of the methods presented in table 2 can be used as a preparation to initiate a BEaMS project, and we argue that it is not necessary to follow all activities in the list to kick off a project in practice. The selection and combination of the activities can be different according to the preference and the criteria of the involved organizations and consulting parties. Usually, it is the consulting parties who have the ability to organize such activities, according to the initiatives from the organizations. We assume that the consulting parties are external here, though it is also possible that they come from within an organization in some cases.

In addition, the analysis framework presented in chapter 2 may also be used to help decision makers to focus on relevant issues during the engineering mobility phase. Particularly, it helps managers to evaluate the complexity and the coverage of the issues of a proposed mobile workforce solution; it raises awareness for the need to apply an appropriate engineering approach to deal with the complexity of the situation. We argue that the framework may also help managers to predict circumstances where deploying mobile workforce solutions would add value, and it can serve as a checklist for guiding decision makers through this step.

Methods	Description
Tutorial	Tutorials about mobile & wireless technology. Mainly aimed at organizations that have initial interests on mobile solutions or other special interest groups.
Awareness Session	An awareness session is a workshop in which we in an interactive way make the participants aware of the developments in the field of mobile and wireless technology. In this presentation we focus on four areas of interest: network technology, mobile & wireless devices, users, applications.
Concept Generation	Concept generation introduces a creative workshop aimed at intensifying the birth of new ideas. Ideas that in normal circumstances would not have arisen. For this, various techniques can be used, for example, a brainstorming session using group support systems (GSS).
Cross Market Analysis	A cross market analysis gives a client organization insight into the way a specific mobile & wireless technology or application has been effected in markets different from the one that the customer is in.
Quick Scan	The quick scan is a study that gives the customer a first insight into specific mobile applications for their business. According to a standard format a scan is made of the external and internal environment of the company to get a first impression of feasibility. Further a first analysis is made to define the financial consequences.
Internal Business Scan	An internal business scan is a study in which the internal processes and capabilities of the company are analyzed. The analysis gives an overview of the issues that need to be solved to implement mobile application without running into problems.
Business Case Analysis	A business case analysis is a numerical substantiation of the consequences of the implementation of a mobile application. All relevant income and expenditure are mapped in a spreadsheet.

Table 1 List of methods for the mobility engineering activities at phase one

Appendix 3 Assumption and specification of the simulation model of the illustration case G4

For this case we assumed that G4 has 10 customers, named customer 0 to customer 9. Each of them has an Exponential order distribution giving the total occurrences of an alarm with *mean* values ranging from 70 to 150 minutes. Details of the values that were used for the order rates for each of the 10 customers are given in table below.

Customer	**Parameters**
Customer 0	Expo(80)
Customer 1	Expo(90)
Customer 2	Expo(75)
Customer 3	Expo(105)
Customer 4	Expo(150)
Customer 5	Expo(140)
Customer 6	Expo(120)
Customer 7	Expo(70)
Customer 8	Expo(110)
Customer 9	Expo(90)

Table 2: Parameters of order rates

There is only one product type in this case: the alarm. With regards to the quantity preferences a logical assumption was made to restrict the alarm to one, supported by the assumption that only one alarm can go off in a building. The onsite service time distribution was assumed to be an exponential one with a mean value of 5 minutes, the processing time distribution was also implemented as an exponential distribution with a mean value of 2 minutes. Since in this case there are no physical products (i.e. NonProductServing mode), the pick up time distribution was set to "null".

Further, we made the assumption that there are 4 mobile workers available at all times, and as such the effects of changing shifts could be disregarded. All requirements concerning skill and skill levels were leveled. This meant that every worker could intervene an alarm. We also made an assumption that the roads did not have any speed values, and assigned a default speed value of 30, which can be translated according to the maps scale of 1: 120 meters to an approximate speed of 40 km/h. For the dispatching policy we implemented an algorithm which selects the worker with the smallest estimated time of arrival (ETA).

After the dispatch center receives an alarm, it sends a call to all mobile workers to report their work list and their current activity. Using this information the dispatch center using the dispatching policy, calculates the ETA of each worker and selects the worker with the smallest estimated time. This experiment is run in units of minutes for 7 days, a week, or 24 hours a day, in which the customers constantly fire the alarm, according to the order distribution. We present the implementation of the dispatching policy used in the simulation model next.

G4SmallestETAPolicy

```
package nl.tudelft.simulation.beems.policy;

import java.util.List;
import nl.tudelft.simulation.beems.model.DispatchCenter;
import nl.tudelft.simulation.beems.model.Order;
import nl.tudelft.simulation.beems.model.WaitActivity;
import nl.tudelft.simulation.beems.model.Worker;
import nl.tudelft.simulation.beems.model.World;


public class G4SmallestETAPolicy extends AbstractDispatchPolicy {

        /**
         * @param dispatchCenter
         */
        public G4SmallestETAPolicy(final DispatchCenter dispatchCenter) {
                super(dispatchCenter);
        }


        /**
         * @see nl.tudelft.simulation.beems.policy
         * .DispatchPolicyInterface#selectOrder(java.util.List)
         */
        Public Order selectOrder(List<Order> orders) {
                // Get the first order
                return orders.get(0);
        }

        /**
         * @see nl.tudelft.simulation.beems.policy
         * .DispatchPolicyInterface#selectWorker(java.util.List,
         *  nl.tudelft.simulation.beems.model.Order)
         */
        public Worker selectWorker(List<Worker> workers, Order order) {
                // Get worker with smallest ETA
                Worker worker = null;
                double ETA = Double.MAX_VALUE;

                for(Worker current: workers){
                        double workerETA = getWorkerETA(current, order);
                        if(workerETA < ETA){
                                ETA = workerETA;
                                worker = current;
                        }
                }
                return worker;
        }

        private double getWorkerETA(Worker worker, Order order){
                double ETA = 0;
                /**
                 * if worker isn't busy, ETA is the time needed
                *  to reach the order destination, as the speed values are
                * constand, there's no difference between distance and
                * time needed to cover the distance for the calculation of
                * the ETA
                 */
                if(worker.getActivity() == null ||
                                           worker.getOrders().isEmpty()){
                ETA = PolicyUtility.
                   distance(worker.getRealLocation(), PolicyUtility
                  .findOrderDestination(order).getLocation());
                }
                else{
                        List<Order> orders = worker.getOrders();
                        Order currentOrder = orders.get(0);

                        //add remaining time for current order
                      if(worker.getActivity().getName()
                                                .equals("Traveling")){
```

```
                    ETA = PolicyUtility
                       .distance(worker.getRealLocation(),
                       PolicyUtility

                            .findOrderDestination(currentOrder)
                            .getLocation())
                        +currentOrder.getDeliveryTime();
            }
            else if(worker.getActivity().getName()
                                        .equals("Waiting")){
                    WaitActivity temp = (WaitActivity)
              worker.getActivity();
                    ETA = World.simulator.getSimulatorTime() -
                    temp.getStartTime();
            }

            //add time for remaining orders
            for(int index = 1; index < orders.size(); index++){
              Order current = orders.get(index);
                    ETA += PolicyUtility
                     .distance(PolicyUtility
                     .findOrderDestination(currentOrder)
                     .getLocation(), PolicyUtility
                            .findOrderDestination(current)
                     .getLocation())
                        + current.getDeliveryTime();

                    currentOrder = current;
            }

            // finally add time needed to travel from last order
           // destination to new order destination
        ETA += PolicyUtility.distance
            (PolicyUtility.findOrderDestination(currentOrder)
            .getLocation(), PolicyUtility
               .findOrderDestination(order).getLocation());
        }
        return ETA;
    }

}
```

Appendix 4 Assumption and specification of the simulation model of the illustration case KCI

In this case we made an assumption that there were five customers. An order can be seen as an event occurring in a given time, and therefore it is given a timestamp. We chose to use the Exponential distribution for the customer order rate following our discussion in subsection 5.2.1. Details of the values that were used for the order rates for each of the 5 customers are given in table 3.

Customer	Parameters
NursingCenter	Expo(60)
CentralHospital	Expo(80)
TherapyCenter	Expo(90)
DoctorsOffice	Expo(90)
PrivateHospital	Expo(125)

Table 3: Parameters of order rates

We assumed that a customer cannot order more products than that the mobile worker can carry. For instance if the maximum stock of a product type is 5, the order quantity of this product type cannot exceed 5. We also made an assumption that there were three product types with different requirements concerning the skill levels and the maximum instances of that product which can be carried in a car. For the quantity and order preferences we chose to use triangular distributions to support our assumptions.

As specified in chapter 5.2.1 the processing time distribution should be specified as an exponential distribution and the onsite service time distribution as either a gamma or exponential distribution. In this case we chose to use the exponential distribution for the onsite service time. The parameters of the exponential distribution for the processing and onite service times were assumed to be 5 and 10 minutes respectively.

For the pick up time distribution we chose a uniform distribution with parameters 10 and 15 minutes. Stock was assumed to be unlimited at the pick up locations. The main inventory was assumed to be located at the dispatch center. We made the assumption that there were 3 mobile workers available at all times, each of them with different *skill levels*, so that not every worker could handle every order. To implement this assumption, a check for correct skill was included in the dispatching policy. Each mobile worker was implemented in such a way that they carried an inventory of certain products (not all). To implement this, a check for sufficient stock or reload was also included. For the reloading part we assumed that the whole inventory of one worker would be maximized when the worker reloads.

The worker allocation function selects the worker with the smallest ETA. To determine the speed we set a default speed value. Considering that the number of orders was expected to be low (per day) we ran this experiment for one whole weeks (24-7) with the assumption that every order was urgent so the response time was set to a minimum. As was the situation with the other illustration case, the workers were able to change shifts without interfering with the delivery process, for instance when reloading at the inventory.

Based on the above assumptions, a model was specified in the *world_KCI.xml* file. Just as in the previous G4 case, any of the building blocks that were not required to fulfill a given function during the simulation run did not have to be specified. Next, we present the implementation of the dispatching policy used in the simulation model.

KCISmallestETAPolicy

```
package nl.tudelft.simulation.beems.policy;

import java.util.List;
import java.util.Map;

import nl.tudelft.simulation.beems.model.DispatchCenter;
import nl.tudelft.simulation.beems.model.Order;
import nl.tudelft.simulation.beems.model.OrderStatus;
import nl.tudelft.simulation.beems.model.WaitActivity;
import nl.tudelft.simulation.beems.model.Worker;
import nl.tudelft.simulation.beems.model.World;


public class KCISmallestETAPolicy extends AbstractDispatchPolicy {

	/**
	 * @param dispatchCenter
	 */
	public KCISmallestETAPolicy(final DispatchCenter dispatchCenter) {
		super(dispatchCenter);
	}

	/**
	 * @see nl.tudelft.simulation.beems.policy
	* .DispatchPolicyInterface#selectOrder(java.util.List)
	 */
	public Order selectOrder(List<Order> orders) {
		// Get the first order
		return orders.get(0);
	}

	/**
	 * @see nl.tudelft.simulation.beems.policy
	 * .DispatchPolicyInterface#selectWorker(java.util.List,
	 *      nl.tudelft.simulation.beems.model.Order)
	 */
	public Worker selectWorker(List<Worker> workers, Order order) {
		// Get worker with smallest ETA
		Worker worker = null;
		double ETA = Double.MAX_VALUE;

		 //only check the ETA of workers with required skill
		  List<Worker>skilledWorkers =
		            PolicyUtility.findSkilledWorkers(workers, order);

		for(Worker current: skilledWorkers){
			double workerETA = getWorkerETA(current, order);
			if(workerETA < ETA){
				ETA = workerETA;
				worker = current;
			}
		}

		return worker;
	}

	private double getWorkerETA(Worker worker, Order order){
		double ETA = 0;
		//if worker isn't busy, ETA is the time needed to reach the
		//order destination, as the speed values are constant,
		//there's no difference between distance and time needed to
		// cover the distance for the calculation of the ETA
		if(worker.getActivity() == null ||
		                         worker.getOrders().isEmpty()){
			//also check if worker has sufficient stock
			if(worker.getInventory().containsKey(order
			  .getProductType().getName()) &&
```

```
                order.getQuantity() < worker.getInventory()
                          .get(order.getProductType().getName())){
                        ETA = PolicyUtility.distance
                             (worker.getRealLocation(), PolicyUtility
                             .findOrderDestination(order)
                             .getLocation());
                }else{
                        ETA = PolicyUtility.distance
                              (worker.getRealLocation(),
                              order.getPickupLocation()
                              .getLocation())
                           + order.getPickupTime()
                             + PolicyUtility.distance
                        (order.getPickupLocation().getLocation()
                        , PolicyUtility
                                .findOrderDestination(order)
                        .getLocation());
                }
        }
        else{
                List<Order> orders = worker.getOrders();
                //a temporary inventory to store the
                //stock values to be
                Map<String, Integer> inventory =
                                        worker.getInventory();
                Order currentOrder = orders.get(0);

                //add remaining time for current order
                if(worker.getActivity().getName()
                                       .equals("Traveling")){
                 //two cases: worker traveling to pick up
                 //location or worker traveling to order
                 //location
                        if(currentOrder.getOrderStatus() ==
                                         OrderStatus.SHIPPED){
                                ETA = PolicyUtility.distance
                                      (worker.getRealLocation()
                                     ,PolicyUtility
                                        .findOrderDestination(currentOrder)
                                      .getLocation())
                                    +currentOrder.getDeliveryTime();
                        }else{
                                ETA = PolicyUtility.distance
                                      (worker.getRealLocation(),
                                      currentOrder.getPickupLocation()
                                      .getLocation())
                                    + currentOrder.getPickupTime()
                                    +PolicyUtility.distance(currentOrder
                              .getPickupLocation().getLocation(),
                              PolicyUtility.findOrderDestination
                              (currentOrder).getLocation())
                                    + currentOrder.getDeliveryTime();
                        }
                }
                else if(worker.getActivity().getName()
                                           .equals("Waiting")){
                        WaitActivity temp = (WaitActivity)
                                           worker.getActivity();
                        //Also two cases:worker is loading the product
                        //or worker is delivering the product
                        if(currentOrder.getOrderStatus() ==
                                         OrderStatus.SHIPPED){
                                ETA = World.simulator.getSimulatorTime()
                            - temp.getStartTime();
                        }else{
                                ETA = World.simulator.getSimulatorTime()
                                    - temp.getStartTime()
                                   + PolicyUtility.distance
                              (currentOrder.getPickupLocation()
                              .getLocation(), PolicyUtility
                                      .findOrderDestination
                              (currentOrder).getLocation())
                                    +currentOrder.getDeliveryTime();
                        }
                }
                //update the temporary inventory if this worker can
               // hold this product in its inventory
```

```
                            if(inventory.containsKey(currentOrder
                         .getProductType().getName())){
          int newStock = inventory.get(currentOrder
                          .getProductType().getName())
                        - currentOrder.getQuantity();

          inventory.put(currentOrder.getProductType()
                  .getName(), newStock);
      }
      //add time for remaining orders
      for(int index = 1; index < orders.size(); index++){
       Order current = orders.get(index);
          if(inventory.containsKey(current
            .getProductType().getName()) &&
          current.getQuantity() < worker.getInventory()
               .get(current.getProductType().getName())){

                 ETA += PolicyUtility.distance
                        (PolicyUtility.findOrderDestination
                        (currentOrder).getLocation(),
                         PolicyUtility
                          .findOrderDestination(current)
                          .getLocation())
                    + current.getDeliveryTime();
          }else{
                 ETA += PolicyUtility.distance
                (PolicyUtility.findOrderDestination
                (currentOrder).getLocation(),
                current.getPickupLocation()
                .getLocation())
                     + current.getPickupTime()
                     + PolicyUtility.distance
                (current.getPickupLocation()
                .getLocation(), PolicyUtility
                        .findOrderDestination(current)
                    .getLocation())
                     + current.getDeliveryTime();
          }

          //update the temporary inventory if thisworker
          // can hold this product in its inventory
          if(inventory.containsKey(current
                       .getProductType().getName())){
                 int newStock = inventory.get(current
                               .getProductType()
                               .getName()) - current
                               .getQuantity();
                 inventory.put(current.getProductType()
                            .getName(), newStock);
          }
          currentOrder = current;
      }

      //finally add time needed to travel from last order
      // destination to new order destination
      if(inventory.containsKey(order.getProductType()
          .getName()) && order.getQuantity() <
          worker.getInventory().get(order.getProductType()
          .getName())){

          ETA += PolicyUtility.distance(PolicyUtility
                 .findOrderDestination(currentOrder)
                 .getLocation(), PolicyUtility
                 .findOrderDestination(order)
                 .getLocation());
      }else{
          ETA += PolicyUtility.distance(PolicyUtility
                 .findOrderDestination(currentOrder)
                 .getLocation(), order
                 .getPickupLocation().getLocation())
              + order.getPickupTime()
              + PolicyUtility.distance(order
          .getPickupLocation().getLocation(),
          PolicyUtility.findOrderDestination(order)
                 .getLocation());
      }
}
return ETA;
```

Summary

Introduction
Over the last few years, there has been a growing tendency for organizations to change the ways of doing their business from less efficient to more efficient ways of working. The ever changing economic and work environment requires organizations to be able to use information better, to learn faster, to be proactive rather than reactive, and to foster innovation while managing risks. Even though the adaptation to the new work environment is desirable, with mobile services emerging as enablers for improving business processes they create new spaces for applying business engineering, and also bring many challenges and risks. One of the main challenges is to improve the effectiveness of business engineering and mobile services. This challenge is caused by the following constraints: the classic business engineering approach is based on electronic services that are enabled by IT technology, while mobile services expand the boundary of "fixed" electronic services. The research presented here is based on the challenges faced in performing business engineering enabled by mobile services, meaning that this research forms an interface between mobile services and business engineering.

Research on decision support and business engineering reveals that support environments have profound effects on the outcomes of business engineering projects. We saw a clear need for a support environment that incorporates the essential features of the business engineering and mobile services (BEaMS) field. In this research, simulation is considered to be an effective method of inquiry for improving the effectiveness of business engineering and mobile services in organizations. It can be used to provide insight into the business processes that are enabled by mobile services, and to provide the possibility of carrying out 'what-if' analysis with different scenarios without having to perform the actual implementation of the solution. Based on this reasoning, we formulated the research objective as follows: *to develop a simulation based support environment that can be used to improve the effectiveness of business engineering and mobile services (BEaMS) in organizations.* To meet this objective, we developed four research questions as follows:

- What are the current and emerging issues in practice of BEaMS?
- What are appropriate concepts to constitute the simulation based support environment?
- What are recipes and what are contents of the suite?
- What is the added value of using the support studio in the process of BEaMS?

In this research, we focused on effectiveness as the criteria to improve the process of business engineering and mobile services.

Research methodology
To address these research questions, we used the inductive-hypothetic model cycle to study, develop, and evaluate a simulation-based support studio for BEaMS projects. Various research instruments were used in this research. We performed a literature review to obtain information on the current and emerging issues in the field, to enable us to get a starting point for the research and to sharpen our initial ideas arising from the case studies. The exploratory case studies were used to provide a better understanding of the factors that influence the uptake of mobile technology in supporting business processes. We used two illustration cases to test the support studio on the dimensions of usefulness and usability, and we used expert interviews to gather feedback on how valuable the support studio is in the field of mobile business engineering.

Mobile services and business engineering in organizations

A literature review was conducted to identify a number of initial theories that could be applied to the problem under investigation, i.e. business engineering and mobile services in organizations. We studied mobile services in B2E environments, and described some areas in which B2E mobile services can be expected to show benefits. These included mobile sales-force automation, mobile supply chain management, mobile access to email, personal information management applications, mobile tracking and tracing, and ad hoc planning and scheduling of personnel. Mobile services were defined as the delivery of information, communication, and transaction using a mobile device. The term service in this definition is used to represent non-tangible products that create value for the person(s), or organization(s) receiving them. The literature review showed that a number of services to support business process have been developed to address the needs of workers whose work situation is inherently mobile. Designing such mobile services involves complex activities and involves many actors i.e. problem owners and stakeholders, who have different goal and objectives in the design process. Although different design approaches have been proposed or practiced, none of these approaches are rooted in a problem solving thinking. To form a problem solving based design approach, it is worthwhile to adopt a business engineering perspective.

Support studio for BEaMS

Based on the exploratory case and a literature review, four requirements were formulated for the support studio to satisfy so that it could be used to improve the BEaMS effectiveness. The first requirement stresses that the studio should provide guidelines that enable decision makers to increase awareness of mobile workforce solutions on organizations, and trigger a proactive approach for BEaMS. The second requirement stresses the need for the support studio to facilitate effective communication between stakeholders involved in the BEaMS project. The third requirement stresses on enabling service designers to focus their attention on relevant issues during the design of a mobile solution. The fourth requirement stresses the need to capture effective "as-is" models of the business processes targeted by the BEaMS project, and to support the decision makers in performing "what-if" analysis of the proposed mobile solution. The construct of the support studio consists of landscaping guidelines, initiating guidelines, recipes and suites. This construct is in line with the methodology defined by Sol (1990) using the "four ways" framework: way of thinking, way of controlling, way of working and way of modeling.

Landscaping and initiating guidelines

The landscaping guidelines are used to reflect the way of thinking and the way of controlling for a BEaMS project. The functionality of the support studio depends on the underlying philosophy or way of thinking used to look at the problem situation and information systems under consideration. In the landscaping and initiating guidelines, we delineate the view on BEaMS projects, and provide methodological principles on which the recipes and the suite are based. These methodological principles are rooted in the systems thinking, multi-actor perspective, and business engineering approach.

Recipes

The recipes of the support studio are operational and reinforce a way of working. The recipes are structured in line with the assumption of the three phases of a BEaMS project. The first phase is concerned with performing a business requirements study, creating a strategy with which to formulate the BEaMS project, and forming the team to carry out the project. The second phase is concerned with conducting a thorough business requirements study for the BEaMS project with a focus on process design. The third phase is concerned with developing the mobile solution and deploying it in the organization. We limited the focus of the recipes to the first two phases of a BEaMS project. For the activities of the first phase, we provide recipes on how the initial business requirements study is carried out, how to formulate a BEaMS project, and how to establish the project team and kick off the project. For the activities of the second phased, we provide recipes for carrying out a business analysis with a focus on process and service design issues. The targeted users of the recipes are mainly the business analysts and mobile service designers of a BEaMS project In particular, we emphasize the essential steps to follow to carry out a thorough analysis in phase two, in which we argued for the use of dynamic modeling approach to identify and simulate the business processes that a mobile solution could be used to support. These steps include identifying existing core business processes, assessing potential for improvement by the opportunities of mobile services, mapping alternative business processes based on the results of mobile services, analyzing alternative business processes by simulation, and deducting general conditions and requirements for services and systems design.

These steps are of the core interest to enable a dynamic view on process analysis, and to ensure a process driven approach for mobile service design. To facilitate the implementation of these steps, we identified the need to provide a supporting simulation suite. We further elaborated three functionality requirements that have to be met by the suite, i.e. support the demonstration of key changes of the proposed mobile solutions on business processes, support quantitative analysis of key system performance indicators through statistics features, and support the evaluation of different experiment results through animation feature.

Suite

The suite was developed to reflect our recommendations on the way of modeling. We considered the use of a simulation suite for deployment within the studio as the best way for modeling the dynamics inherent in a mobile workforce related business process. An suite was defined as a domain specific simulation library.

The implementation of the classes in the simulation library uses the concept of building blocks. The building blocks are independent of each other, each representing a specific element of field service processes. The change or replacement of one building block will not affect the functionality of the other building blocks. This ensures the flexibility and extendibility of the simulation library with regards to its contents. Moreover, the simulation library was developed using the Java programming language, which ensures the platform independence of the simulation library.

We chose a discrete event simulation-based approach, i.e. dynamic modeling approach, to form our view on object oriented modeling and simulation. The building blocks were conceptualized and specified based on our study on the domain of field service processes. Within the domain, we limited the scope of the library to the simulation of the dynamics of new dispatching processes enabled by location based services, since dispatching processes pose the most common problems as perceived from the literature and actual practice. The basic building blocks conceptualized are Customer, DispatchCenter, Order, CustomerCenter, MobileWorker, and RoadMap. The exogenous inputs, experiment variables, and performance measures that needed to be included in the library were identified, formulated and specified based on literature, empirical data, and assumptions made in this research.

The implementation of the building blocks was rooted in the Distributed Simulation Object Library (DSOL). DSOL is a Java-based open source simulation language that supports all activities but conceptualization in a simulation study. We used the DEVSSimulator, a DEVS formalism based simulator, provided by DSOL to serve as the simulation engine in our suite. The suite provided a Java library of simulation building blocks which can be used to model and simulate mobile field service processes, especially for dispatching and scheduling processes. It contains objects representing mobile workers, customers, orders, product types, roads, and dispatch centers. A complete model can be specified using the XML input files, which are parsed to instantiate the required objects, their initial conditions, and the experiment configuration.

Illustrating the use of the support studio
The simulation suite was tested using two case studies based on the requirements that were identified for the simulation-based support studio. Through the tests, we were able to demonstrate the key changes that would occur in the business processes if the new dispatching and allocation policies were applied to a mobile workforce. Using the parameters provided, e.g. processing time, delivery time, etc., the decision makers can experience and gain insight in the dynamics of a new business process. Using the animation feature of the simulation suite, we were able to visualize the execution of some business processes. Overall, the functional requirements of the suite were met, and we argue that the suite can be presented to the experts to determine the value it adds to their BEaMS work.

Evaluating the support studio
In addition to the testing case studies, the support studio was evaluated using expert interviews based on the four requirements that were identified for the studio, supplemented with aspects on the three dimensions of usability, usefulness, and usage. The experts agreed that with the support studio, decision makers can become more aware of the business processes involved in defining the mobile service. The approach of designing a mobile service together with other stakeholders helps to initiate successful results. An appropriate use of the simulation suite helps to provide insight and shared views among the stakeholders. The experts were satisfied with the studio-based approach as applied in the illustration cases, taking into account their experience with other design approaches. The experts agreed that the recipes were helpful in engineering a mobile solution more effectively. In conclusion, the experts were confident with the usability of the suite and did not find any theoretical barrier to using the support studio to improve the effectiveness of BEaMS.

Conclusions and recommendations
Based on the research, we conclude that the support studio is potentially useful, and usable to improve the effectiveness of organization's approach for BEaMS. The support studio can be used to help in the engineering of mobile workforce solutions and to perform 'what-if' analysis that enables the stakeholders to explore new ways of determining the effects of mobile services on business processes. During the research, a number of issues were addressed and a number of other new issues arose that require further research. One possible direction for future research is to test the usability and usefulness of the support studio in real BEaMS projects using action research, involving decision makers and business analysts drawn from the industry. The second possible direction for research is to test the usability and usefulness of the support studio by involving decision makers who are likely to use the studio directly in their BEaMS practice. The third possible direction is to do research on how the suite can be further developed with expanded functionalities that cover a complete business function. It is also interesting to identify usage related requirements from practice to come up with a complete the set of requirements for decision enhancement to improve the effectiveness of BEaMS in reality. The final possible direction for further work is to carry out research into the recipe that can be used by consulting firms to carry out business engineering projects without the need to develop a new studio each time.

Samenvatting

Inleiding

De afgelopen vijf jaar tonen een duidelijke trend dat bedrijven hun werkwijze efficiënter maken. De aanhoudende verandering van economische omstandigheden en van de werkomgeving dwingt organisaties om beter gebruik te maken van beschikbare informatie, om sneller te leren, pro-actief in plaats van reactief te zijn, innovatie te stimuleren en tegelijkertijd risico's te beperken. Hoewel zo'n aanpassing aan de nieuwe werkelijkheid wenselijk is, creëren de mobiele diensten niet alleen ruimte voor het verbeteren van bedrijfsprocessen, maar brengen zij ook onzekerheden en risico's met zich mee. Eén van de belangrijkste uitdagingen is het verbeteren van de effectiviteit van de bedrijfsprocessen door middel van mobiele diensten. Dit is te wijten aan het feit dat de klassieke business engineering berust op IT als ondersteuning van bestaande diensten, terwijl mobiele technologie de grenzen van zulke diensten juist kan verleggen. Dit onderzoek beantwoord de uitdagingen bij het ontwerpen van mobiele diensten, met als doel een brug te slaan tussen mobiele diensten en business engineering.

Onderzoek naar beslissingsondersteunende systemen bij business engineering toont dat een beslissingsondersteunende omgeving sterk bepalend is voor de resultaten. We zagen een duidelijke behoefte aan een ondersteunende omgeving die de essentiële kenmerken van business engineering met mobiele diensten (BEaMS) omvat. Dit onderzoek laat zien dat simulatie een doeltreffende onderzoeksmethode is om de effectiviteit van business engineering van mobiele diensten te verbeteren. Simulatie maakt via "what-if" analyses het ontwerpen van zulke systemen effectiever en efficiënter: verschillende scenario's kunnen vergeleken worden zonder de oplossingen daadwerkelijk te hoeven implementeren. Om deze redenen hebben we ons onderzoeksdoel als volgt geformuleerd: ontwikkel een simulatieomgeving die de effectiviteit van business engineering met mobiele diensten (BEaMS) in organisaties verbetert. Om deze doelstelling te realiseren hebben we ons deze vier onderzoeksvragen gesteld:

- Wat zijn de huidige en komende vragen in de praktijk van BEaMS?
- Welke concepten zijn geschikt om samen een op simulatie gebaseerde support environment te vormen?
- Zijn er recepten, en waaruit moet een suite (domeinspecifieke simulatie-bibliotheek) bestaan?
- Wat is de toegevoegde waarde van een studio in het BEaMS-proces?

In dit onderzoek richtten we ons met name op het criterium effectiviteit bij verbetering van het ontwerpen van bedrijfsprocessen met mobiele diensten.

Onderzoeksmethode

Om de onderzoeksvragen te beantwoorden hebben we de inductief-hypothetische modelcyclus gebruikt bij het bestuderen, ontwikkelen en evalueren van een op simulatie gebaseerde ontwikkelomgeving voor BEaMS-projecten. In dit onderzoek hebben we verschillende onderzoeksinstrumenten gebruikt. We hebben een literatuuronderzoek verricht om een beeld te krijgen van de ontwikkelingen in het betreffende veld, om een startpunt te vinden voor het onderzoek en om de ideeën die voortkwamen uit de case studies verder aan te scherpen. De verkennende case studies zijn gebruikt om beter begrip te krijgen van de factoren die de acceptatie van mobiele technologie als ondersteuning van bedrijfsprocessen beïnvloeden. We hebben twee illustratieve casussen gebruikt om de studio te testen op het punt van nut en bruikbaarheid, en we hebben experts ondervraagd om terugkoppeling te krijgen over de waarde van de support studio bij de ontwikkeling van mobiele bedrijfsprocessen.

Mobiele diensten en business engineering

De beschikbare literatuur is onderzocht op theorieën die bruikbaar waren als startpunt voor ons onderzoek naar het (her)ontwerpen van bedrijfsprocessen met mobiele diensten in organisaties (BPR/BPE). We hebben mobiele diensten bestudeerd in B2E (Business-to-Employee) omgevingen, en enkele gebieden aangegeven waarin B2E mobiele diensten naar verwachting voordelen zullen bieden, zoals: automatisering t.b.v. de mobiele verkoopstaf, mobiel beheer van supply chains, mobiele toegang tot email, applicaties voor het beheren van persoonlijke informatie, mobiele tracking and tracing, en ad-hoc plannen en inzetten van personeel. We hebben mobiele diensten daarbij als volgt gedefinieerd: het verzorgen van informatie, communicatie, en transacties met behulp van mobiele apparatuur. Hierbij definiëren we het woord "dienst" als een niet-tastbaar product dat een waarde vertegenwoordigt voor de personen of organisaties die het product ontvangen. Het literatuuronderzoek liet zien dat veel diensten voor bedrijfsprocessen zijn ontwikkeld ten behoeve van personeel waarvan het werk inherent mobiel is. Het ontwerpen van zulke mobiele diensten vereist complexe activiteiten en omvat diverse actoren (waaronder probleemeigenaars en andere belanghebbenden) die bij het ontwerpen verschillende doelen nastreven. Hoewel verschillende ontwerpbenaderingen zijn voorgesteld en ook toegepast, berust geen ervan op een probleemoplossende denkwijze. Om een ontwerpbenadering te vinden die is gebaseerd op probleemoplossend werken, is het nuttig om er naar te kijken vanuit het gezichtspunt van het ontwerpen van bedrijfsprocessen.

Een support studio voor BEaMS

Op basis van de verkennende case studies en het literatuuronderzoek zijn vier eisen geformuleerd waaraan de support studio moet voldoen om de effectiviteit van BEaMS te verbeteren:

- de studio moet richtlijnen geven om besluitvormers meer bewust te maken van mobiele workforce oplossingen, en hen een proactieve houding geven ten aanzien van BEaMS,
- de ontwikkelomgeving moet effectieve communicatie mogelijk maken tussen alle betrokkenen bij het BEaMS projekt,
- de ontwerpers van diensten moeten hun aandacht kunnen richten op zaken die relevant zijn voor de ontwikkeling van mobiele oplossingen,
- er moeten niet alleen effectieve "as-is" modellen gemaakt kunnen worden, maar het moet ook mogelijk zijn om "what-if" analyses te maken van de voorgestelde mobiele oplossing(en).

Het ontwerp van de studio omvat richtlijnen voor het in kaart brengen van het probleemgebied, richtlijnen voor het initiëren van projecten, recepten (werkwijze) en suites (modelleringswijze). Dit is in lijn met het "vier wijzen" raamwerk van Sol (1990): denkwijze, beheerswijze, werkwijze, en modelleerwijze.

Richtlijnen voor het in kaart brengen en initiëren van projekten

De richtlijnen voor het in kaart brengen van het probleemgebied zijn een weergave van de denk- en beheerswijze van een BEaMS projekt. De functionaliteit van de support studio is het resultaat van een onderliggende "filosofie" of denkwijze bij het beschouwen van de probleemsituatie en van informatiesystemen. Aan de hand van deze richtlijnen bepalen we ons gezichtspunt in BEaMS projekten en geven we de methodologische principes waarop de recepten en de suite zijn gebaseerd. Deze principes berusten op systeemdenken, het multi-actor perspectief, en business engineering.

De recepten

De recepten van de support studio zijn operationeel van aard en moedigen een bepaalde manier van werken aan. De structuur van recepten komt overeen met de drie fasen van een BEaMS projekt. De eerste fase betreft het onderzoeken van de eisen die aan het bedrijfsproces worden gesteld, het bepalen van een strategie om het BEaMS projekt te formuleren, en het formeren van een projectteam. De tweede fase behelst het nader onderzoeken van de eisen aan het BEaMS projekt, met daarbij de nadruk op het procesontwerp. De derde fase betreft het ontwikkelen en in bedrijf stellen van een mobiele oplossing in de organisatie.

We hebben de recepten beperkt tot de eerste twee fasen van een BEaMS project. De activiteiten van de eerste fase betreffen het vaststellen van het initiële programma van eisen, het formuleren van een BEaMS project, het formeren van een projectteam, en de kick-off van het project. Voor de activiteiten van de tweede fase geven we recepten voor het uitvoeren van een systeemanalyse met nadruk op het ontwerpen van processen en diensten. De doelgroep van de recepten bestaat vooral uit systeemanalisten en ontwerpers van mobiele diensten in BEaMS projecten. De nadruk ligt op het stapsgewijs uitvoeren van de tweede fase. We pleiten ervoor via dynamisch modelleren bedrijfsprocessen die door mobiele oplossingen ondersteund zouden kunnen worden te identificeren en te simuleren. Deze stappen omvatten het identificeren van bestaande core business processen, het vaststellen van mogelijkheden om processen te verbeteren door middel van mobiele diensten, het simuleren van alternatieve bedrijfsprocessen, en het afleiden van algemene voorwaarden voor, en eisen aan, het ontwerp van diensten en systemen.

Deze stappen zijn essentiëel om een dynamische kijk op procesanalyse mogelijk te maken die bij mobiele systemen, en om zeker te stellen dat een procesgedreven aanpak wordt gebruikt bij het ontwerp van mobiele diensten. We hebben verder vastgesteld dat een ondersteunende simulatie-suite de implementatie van deze stappen zal vereenvoudigen. Tenslotte hebben we drie functionele eisen geformuleerd waaraan de suite moet voldoen: ze moet ondersteuning bieden voor het demonstreren van de belangrijkste gevolgen van mobiele oplossingen voor de bedrijfssystemen, ze moet ondersteuning bieden voor kwalitatieve analyse van de belangrijkste prestatie-indicatoren door middel van statistische functies, en ze moet het via animatie evalueren van verschillende experimenten mogelijk maken.

De suite

De suite is zo ontworpen dat zij onze aanbevelingen voor de modelleerwijze volgt. We vinden een simulatie-suite het beste gereedschap om de dynamiek te modelleren die inherent is aan bedrijfsprocessen met mobiele workforces. De suite is gedefinieerd als een domeinspecifieke simulatiebibliotheek.

De implementatie van de simulatiebibliotheek (suite) is gebaseerd op bouwstenen die elk een specifiek element van mobiele onderhoudsdiensten weergeven. Een verandering binnen een bouwsteen heeft geen invloed op het functioneren van de andere, wat de flexibiliteit en uitbreidbaarheid van de simulatiebibliotheek waarborgt. Omdat de simulatiebibliotheek is ontwikkeld in Java wordt bovendien de hardware-onafhankelijkheid van de bibliotheek gegarandeerd.

Bij het modelleren en simuleren hebben we gekozen voor discrete event simulation (een vorm van dynamisch modelleren). Bij het specificeren van de bouwstenen zijn we uitgegaan van de resultaten van ons onderzoek op het terrein van een mobiele onderhoudsdienst. Binnen dit domein hebben we de bibliotheek beperkt tot de simulatie van processen voor het inzetten van mobiel personeel, in het bijzonder die processen die mogelijk worden door location based services, omdat dit soort processen volgens de literatuur en de waarneming in de praktijk voor de meeste problemen zorgen. De bouwstenen die we hebben gedefinieerd stellen klanten, werkverdelers, orders, klantencontactpunten, mobiele werknemers en geografische informatie voor. Inputs die van buiten komen, de variabelen waar we mee willen experimenteren, en de prestatie-indicatoren die in de bibliotheek gerepresenteerd moesten worden zijn geformuleerd op basis van de literatuur, empirisch verkregen gegevens, en aannames zoals verantwoord in ons onderzoek.

De implementatie van de bouwstenen berust op de “Distributed Simulation Object Library (DSOL)”. DSOL is een “open source” simulatiebibliotheek in Java die alle simulatieactiviteiten behalve conceptualisatie ondersteunt. We hebben een op het DEVS-formalisme gebaseerde simulator gebruikt die onderdeel is van DSOL. Onze suite biedt een bibliotheek van simulatiebouwstenen die gebruikt kunnen worden om mobiele processen te modelleren en te simuleren die te maken hebben met de activiteiten van een servicedienst. De bibliotheek bevat objecten die mobiele werknemers, klanten, orders, producttypen, routes en werkverdelers representeren. Een compleet model kan worden beschreven met behulp van XML-files die specificeren hoe de objecten moeten worden geïnstantieerd, wat hun begintoestand moet zijn, en hoe het hele experiment moet worden geconfigureerd.

Illustratie van het gebruik van de support studio

De simulatiesuite is getest aan de hand van twee geschikte case studies. Door middel van deze tests bleken we in staat om de belangrijkste veranderingen te laten zien die zouden optreden in de bedrijfsprocessen als nieuwe strategieën voor de toewijzing en inzet van personeel toegepast zou worden op een mobiele workforce. Met parameters als verwerkings- en levertijd kunnen besluitvormers inzicht krijgen in de dynamiek van het nieuwe bedrijfsproces. Via animatie (ook een onderdeel van de suite) kan uitvoering van verschillende bedrijfsprocessen inzichtelijk gemaakt worden. Daarmee hebben we getoond dat aan de functionele eisen werd voldaan, en nadat de suite aan experts ter beschikking was gesteld kon worden vastgesteld welke waarde de suite toevoegde aan hun werk met BEaMS.

Evaluatie van de support studio

Naast de test met de case studies is de suite ook geëvalueerd door middel van een enquête onder experts. De enquête betrof de vier eisen die eerder waren vastgesteld en de aspecten bruikbaarheid, nut, en feitelijk gebruik. De experts waren het er over eens dat de besluitvormers zich beter bewust worden van de bedrijfsprocessen die betrokken zijn bij het definiëren van een mobiele dienst. Het samen met andere betrokkenen ontwerpen van een mobiele dienst draagt bij aan een succesvol resultaat. Een goed gebruik van de simulatie-suite bevordert inzicht en gemeenschappelijke gezichtspunten bij de betrokkenen. Op grond van hun ervaring met andere ontwerpbenaderingen waren de experts erg tevreden met de studio-gebaseerde benadering zoals gehanteerd in de illustratieve casussen. Ze waren het er ook over eens dat het ontwikkelen van een mobiele oplossing effectiever verliep door toepassing van de recepten. Concluderend: de experts hadden vertrouwen in de bruikbaarheid van de suite en zagen geen belemmeringen voor de invoering van de studio.

Conclusies en aanbevelingen

Op basis van ons onderzoek concluderen we dat de studio nuttig en bruikbaar is als ondersteuning voor BEaMS. De studio kan helpen bij het ontwikkelen van oplossingen voor mobiele workforces en bij “what-if” analyses en daardoor de betrokkenen in staat stellen op een nieuwe manier de effecten te bepalen van mobiele diensten op bedrijfsprocessen. Tijdens zijn ook een aantal nieuwe vragen naar voren gekomen die nader onderzoek vereisen. Eén mogelijke richting voor verder onderzoek is het testen van bruikbaarheid en nut van de support studio in echte BEaMS projecten door middel van “action research” met besluitvormers en bedrijfsanalisten uit de industrie. Een tweede mogelijke richting is het testen van de bruikbaarheid en het nut van de support studio door er besluitvormers bij te betrekken die de studio waarschijnlijk direct zouden kunnen toepassen. Een derde mogelijke richting is om te onderzoeken hoe de suite verder ontwikkeld kan worden om de functionaliteit van een bedrijfsproces volledig af te dekken. Daarnaast is het interessant om op basis van feitelijk gebruik te komen tot een volledige set eisen aan de ontwikkelstudio. De laatste mogelijke richting voor verder werk is te onderzoeken of er een recept is dat kan worden gebruikt bij het uitvoeren van ontwikkelprojecten zonder dat het nodig is daarvoor iedere keer een nieuwe studio te ontwikkelen.

Curriculum Vitae

Yan Wang was born on February 8th 1978 in Tangshan, China. After graduating from Tangshan No. 1 high school in 1994, he studied Acoustics and Electronic Engineering at Harbin Engineering University, China. He did an internship at TI-HEU DSPs Laboratory, where he had an opportunity to participate in a project for the Texas Instrument Digital Signal Processing and Analog Challenge 2000. His team was rewarded with a 3rd place in China. In 2001, he began his Master degree in Systems Engineering, Policy Analysis and Management at Delft University of Technology. His Master thesis project, which was conducted in the Ministry of Transport, Public Works, and Water Management, was about dynamics in the Internet infrastructure at the level of autonomous systems. In 2003, he started his Ph.D. research in the Systems Engineering section of the Faculty of Technology, Policy and Management at Delft University of Technology. Part of his research has been published a number of papers and presented at international conferences. He also organized and taught several tutorials, and supervised several students during their bachelor and master's thesis projects. Furthermore, he has been actively involved in a number of mobile projects with the LogicaCMG consulting company. The following keywords describe his research interests: modeling & simulation, business process engineering, decision making support, and mobile services design.