Managing Projects in an Embedded System Development Context: An in-depth Case Study from an Improvisational Perspective

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Abstract
This paper reports the findings of an empirical investigation into developing and managing an embedded system project in the context of structured process management. This research adopts an interpretive case study approach and explores project managers’ and developers’ experiences in embedded system development within a turbulent environment. The study describes the complex undertaking of managing embedded system development, which, in this case, involved improvisational and bricolage practices. It analyses the various influences on the management of an embedded system development project in this setting, along with the organizational responses to such influences. The paper indicates that improvisation and bricolage might be possible tactics for coping with challenges, and lead to a smooth transition of organizational processes. In this case setting, best practices and principles became informal rules and standards, both of which enabled the project manager to cope with difficulties throughout the project.

1. Introduction
Structured and planned processes seem to dominate the realm of project management. Many articles have been published in the academic and non-academic press that typify and describe ways to handle blatant problems in managing projects. Most of these articles are based on the typical development phases of a project, which are classified as initiation, planning and design, execution, monitoring and controlling, and closing (e.g. [1, 2]). This classification may vary, but its structural element remains the underlying model for carrying out of distinctive steps. Another reoccurring element within project management themes is the focus on the projects scope, costs, presence of time, and, last but not least, the importance of quality (e.g. [1, 2]). The latter has introduced the development of various quality standards, such as the ISO 9001 worldwide quality standard. The International Standard Organization has specified some rules of project management, such as identification of project, specific staffing and project leaders, ex ante definition of milestones, manuals of procedures, and formalized learning accumulation mechanisms [3]. This structured process management framework is seen as successful because an ISO certification delivers various benefits, such as an increase in sales, market share, productivity and efficiency, reduced cost and waste, better managerial control over processes, and improvement in product and service quality [4, 5]. In contrast to the well-explained positive attributes of an ISO certification, there are also some negative aspects of such a certification: the higher degree of process management in an organization, the lesser quantity of exploratory innovations, and less creative and critical thinking in an organization because the workforce is engaged according previously specified procedures and policies [4]. These advantages and disadvantages of structured process frameworks are vital issues for the management of projects, especially because tracking and controlling of projects may be enhanced or stifled through structured processes. For example, in projects dealing with interruptions, risks, conflicts, and commitments, the project managers will need to decide its alignment to structured processes.

In a project context, improvisation and bricolage involves moving away from structured processes in order to speed up the implementation of tasks. These emergent activities in general are positively associated with accelerated product development in turbulent industries [6]. Improvisation also might be seen as an effective behavioral strategy for dealing
with change, particularly under dynamic conditions [7]. Augier and Vendelø [8] claim that improvisation can be considered as a rapid problem-solving technique that might be used by project teams to cope with surprises. Improvisational actions may often involve bricolage, which is defined as making do with the tools or resources at hand [9], but bricolage also occurs when planning precedes execution [10-12]. Innes and Booher [13] describe bricolage as a nonlinear, holistic approach to dealing with a given difficulty in a practical product. Additionally, many researchers portray bricolage and improvisation as a managing strategy to secure organizational reliability [11, 14]. In summary, the difference between improvisation and bricolage is twofold. First, the aspect of collecting and using the items at hand [9] points to a more physical attribute of bricolage, whereas improvisation is more general. Second, bricolage might occur with pre-planning, whereas improvisation does not involve planning activities [10-12]. Because of these differences we include both in our analysis.

These styles (planned and emergent style) contrast each other, influence the progress of projects, and involve skilled project management. In addition, the management of embedded systems is very complex, because it bands together the realms of software and hardware. Embedded system development is fundamentally different to non-embedded systems because it addresses specific constraints such as limited memory and power use, time constraints, predefined hardware platform technology, and hardware costs [15]. The people involved in the development of an embedded system must understand interdisciplinary product application domain knowledge [16] and physical requirements such as power, memory, and real-time issues [15, 17]. We therefore argue that embedded system development has different features and justifies an in-depth investigation.

In addition to the tension between planned and emergent styles of project management efforts, embedded system developments involve various realms and demand a thorough understanding of them by project managers. While there are many studies on planned as well as emergent styles of project management efforts [18], the issue has not been explored in detail in an embedded system development context with structured process management. Furthermore, only a few studies have investigated the influence of bricolage and improvisation on project management in the embedded system development context. This paper aims to address these gaps, by asking some key questions: What may influence the management of an

embedded system development project in an organizational environment of improvisation and bricolage? How do these influences shape the project management? And, what are the implications for theory and practice in such a context? 

In the next section, we present our theoretical foundation, and the third section outlines our research methodology. The forth and fifth sections present our case description and analysis. This paper concludes with a discussion on the implications of our findings for managing embedded system development projects.

2. Theoretical background

The purpose of this research is to derive a theoretical interpretation from empirical data [19]; we also draw on polarized streams to develop our theoretical interpretation. One stream involves a planned style of specified activities and the other is a more emergent style of project development and management efforts.

Planned styles involve the use of a sophisticated methodology. There are three process models of information technology development: specification, evolutionary, and agile development [20, 21]. First, the idea of a specification-driven model is the piecewise execution of defined steps, which direct participants to the initial goals of the entire procedure [20, 22]. Second, evolutionary approaches guide several cycles of the development process to allow for adjustment in the project timeframe [23]. During the cycles, the following topics should be refined [23]: objectives, constraints, alternatives, risks, risk resolution, risk resolution results, planning for the next phase, and commitment. Although the agile development approach is a “lighter” approach toward building information technology [21], it contains several structural guidelines that vary from one characteristic to another. For instance, the early and frequent delivery of working software is essential for agile developers because it is a primary measure of progress [21]. These planned styles have in common the various structural frameworks of ex-ante planning for the entire development process.

However, plans may continually be diverted and surprises arise constantly; predictability is a luxury we cannot afford in a turbulent environment [24]. To address this, Ciborra [24] proposes a range of concepts relating to organization and technology: care taking, hospitality, and cultivation. Care taking refers to the involvement of stakeholders in the daily flow of practices, which contribute to the success of development efforts. A vital form of care taking is
“understanding”. Understanding a system indicates the familiarity of the developers and managers with the information system. The developers and managers exhibit this familiarity by routine actions and practices during the development process. Second, hospitality of developers and managers toward technology arises through two aspects. One is the natural affinity of people related with information technology development toward new technology. The other is the underlying ambiguity of new technology. So, developers and managers are asked to cope with newness and its ambiguity. An unstable way of coping with this setting can turn into hostility. Finally, cultivation is about developing and managing a technology that is in itself dynamic. Information technology development is dynamic, because it is an alignment between strategy, organization, technology, and a turbulent environment. So, cultivation goes beyond planning and constructing to create a coherent socio-technical system. Cultivation relates to the interference and support of the dynamics in information technology development. Ciborra [24] considers this range of concepts as a way to overcome the tension between an overdose of methodologies and the world as it presents itself in our day-to-day experience. Ciborra [25] emphasized the strategic importance of activities such as improvisation and bricolage in everyday life.

Table 1 lists the three process models of information technology development (specification, evolutionary and agile development) as part of the major contributions of the planned style. In addition, the table shows the underlying attributes of the more emergent development style.

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<th>Style Variations</th>
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The research approach adopted to study the development and management activities of a project in an engineering company (EC - pseudonym) was based on an interpretive case study [30]. It involves the collection of detailed, qualitative data on development and management activities in the embedded system context [31, 32]. EC is accommodating ISO 9001 processes throughout the organization and develops high tech products for the automotive market. EC has branches at two locations in Germany with a staff of more than 180 individuals, so it is large enough to provide moderate data for the study. The developers and managers were encouraged to participate and the research was conducted during the development of an embedded system (<Mem-Beth> pseudonym). One of the authors spent an extended period of time with the development team (description in section “Research site context”) to prepare detailed observation notes of EC, its culture, habits and activities. By doing these informal visits from January 2007 until June 2007, we conceived the social character of the developers and managers along with their group activities in a typical setting. Furthermore, we arranged interviews with the key persons of project Mem-Beth. We transcribed 19 interviews (one group interview and 18 semi-structured interviews), each lasting approximately 90 minutes and held within a relaxed atmosphere (Table 2). To encourage the interviewees’, we ensured that their statements remain confidential.
Valuable insights of their reference procedures provided the organizational ISO 9001 documents and other records such as meeting reports. We filed these data sets of qualitative material electronically in order to accelerate and simplify further research progress. Data were read and reread to familiarize researchers with the information and to help determine trends. Particularly, the researchers looked for a better understanding of the development and management activities in an embedded system project. For data analysis we used an approach that is referred to as three-tier-coding [33]. The progress of data analysis is conducted in three steps. First, meaning is attached to the data and the case’s nature is obtained. Second, the context of the selected data is related to the basic phenomenon. The third and final step is the classification of data by its content rather than by the origin of information, and hence to apply patterns. By applying this three-tier-coding procedure to the collected data (interview transcripts, observation notes, organizational documents) we were able to conceive various aspects of the theme of this research (project management of embedded system development). Therefore, we were able to build a bottom-up conceptualization of the collected and analyzed data sets while using two theoretical abstractions (planned and emergent styles of project development and management) as sensitizing devices.

4. Case description

4.1. Research site context

EC is engaged within the automotive sector in Germany, a business field known for high competition. EC’s business model consists of two divisions: to supply services at the customer site within the automobile sector, and to develop high-tech products in that sector. The organization was founded eight years ago, and it has seen profitability since that time. Currently, EC employs more than 180 people, with 39 individuals involved in the development and management of high-tech products. The organization has undergone significant changes because of both its growth and the competition in the sector. Five years ago, EC introduced a structured process management framework. As a consequence, organizational operations such as procurement, marketing, human resources, quality management, and development have been made compliant with ISO 9001. The prescribed processes need to be followed by every department. For example, the product development process was described in detail with eight multifarious figures, 27 documentation outcomes, and 19 links to other documents. Because of the detailed process description, we felt some adherence of the perceived actions and practices by the organizational actors to the established structured process management framework. We concentrated our research on the actions of the middle management, project managers, and associates of the development department.

Twenty-three individuals are engaged with the development and management of project Mem-Beth, which started several years after the introduction of ISO 9001. For studying this phenomenon, we introduce at this point five key persons, because of limited space. The role of the project manager – we call him Martin – was vital for the success of Mem-Beth. During the conceptualization phase of this project, he spent half of his time as a service supplier with the initiator of that new embedded system and half with the development team of this system at EC. Therefore, he had excellent knowledge about the needs of the customer as well as the difficulties of the developers. Gabriel was responsible for the architecture of the new embedded system and he was manager of the software developers. Michael, senior manager and co-founder of EC, was the head of the development department. Esther was involved in general issues of marketing before she became the product manager of Mem-Beth. Finally, Raphael was an outstanding developer and success depended largely on his abilities. Table 3 lists some of the organizational actors whose responses were important for this study.
Again, the developing and managing activities of a new embedded system, which we’ve dubbed Mem-Beth, was the centre of this investigation. Particularly we were interested in the project management issues of that development in a structured process management environment. Mem-Beth was an electronic device based on Linux that used software to connect with various bus communication systems inside a car or similar test equipment. The idea of Mem-Beth was to record all transmissions (especially control messages) on these bus systems and store it on a hard disk. Hence, the customer could connect Mem-Beth to a computer by using its client software and read and analyze the obtained data. Before Mem-Beth was available, the business problem was the reliable gathering of all transmission data, in order to find the error source of the tested equipment inside the automobile. So, the business field was the research and development departments of vehicle manufacturers and their suppliers. The product launch of Mem-Beth caused a considerable change in this market niche.

4.2. Organization and strategy of EC

The organizational framework of EC underwent major changes. Before project Mem-Beth started, eleven individuals were involved with issues of development and project management and at the launch of Mem-Beth eight people were engaged. Although the development progress was observable, the managers decided to hire new staff to cope with the growing complexity. Gabriel explained that it takes time to become acquainted with the organization, its procedures, and the people. There were at the final stage of project Mem-Beth 23 individuals involved with the development and management, whereas the entire development and management departments engaged 39 individuals. It is important to know that this group is differentiated into four different departments with more or less distinctive tasks and responsibilities. However, these departments originated from the development department. In the past, the developers were encouraged to handle a lot more non-development tasks. Project Mem-Beth showed the responsible team managers that EC needs a more sophisticated organization. Michael mentioned that this reorganization was arranged in order to disburden the developers:

“With this enhanced structure, the character of the development department was changed. One reason for this was the necessary compliance to structured processes.”

The organizational structure, its processes, and some intricacies of the day-to-day activities of developers as well as managers altered during project Mem-Beth. Gabriel stated:

“During the initial phase of Mem-Beth there was a lot of tinkering, hacking and patching involved. We had less or no documentations or diagrams. Although the actions are going to be more and more bureaucratic, there is still a significant amount of hacking implicated. Sometimes, we need to tinker, because it seemed to be a quick solution for the complex technical problems.”

The observation notes and informal discussions with many developers concur with this statement. The poor quality of the first samples of Mem-Beth was met with higher efforts to test the final products. The test efforts underwent continual improvement and included hardware, software, and system tests. Previously, lack of quality was reasoned partly in the practice, that the developers were responsible for the quality of their work. However, reoccurring quality issues of Mem-Beth disclosed the dilemma of that procedure. Increases of human resources with responsibilities in the area of quality were a way for EC to cope with the dilemma. Furthermore, the unit volume increased over time; hence, the project became more significant for EC. The original goal of this project was the production of a small number of devices in order to satisfy the requirements of the initial customer. However, the product strategy needed to be adjusted in order to satisfy the growing demand of the initial customer as well as new customers.

4.3. Technical challenges

The technical challenges of Mem-Beth were significantly higher than previous projects of EC. Especially, the requirement elicitation and management was difficult, because some requirements were ambiguous or fluctuating. Martin mentioned that for some parts of Mem-Beth, the customer was very concerned and had specified the requirements in great detail. It is essential to use a specific 16-Bit processor to connect with the vehicle. The software package of this 16-Bit processor...
processor was predetermined and Mem-Beth developers needed to implement it into the system. On the other hand, Martin explained that the 32-Bit and the digital signal processor were not regulated at all. Moreover, the internal departments at EC (marketing, hardware and software development) also had some worries about the technical requirements. For instance, whereas the provided hardware platform initially had a USB adaptor, the software department had no resources to program a USB driver. At some point, Esther (marketing – product manager) decided to leave the USB port out, for cost-effective reasons. Later, the customer inquired about the USB feature. The management of technical issues was an essential part of coping with the turbulent environment of embedded system development. In doing so, a useful weekly meeting was called to discuss recent modifications of Mem-Beth’s requirements. All internal stakeholders were invited to participate and discuss the various technical challenges.

Although the organizational ISO documents had described in some detail how to deal with various problems, the developers and managers claimed that it provided not much help. Gabriel claimed:

“We <developers> at EC are a group of tinkering enthusiasts who like to fix problems. However, this does not mean that we produce results of poor quality.”

Martin stated:

“If we had had more time, then we would have benefited of the ISO processes. Although, I need to confess, that an increased compliance on ISO of people inside EC would have been advantageous for EC.”

We discovered that most practiced procedures concerning the development and management of project Mem-Beth were not prescribed in the organizational ISO 9001 documents. Moreover, the project managers tried to handle difficult situations with informal processes in order to avoid further delays in the project.

4.4. People from EC

Through the increase of human resources, the communication and teamwork differed. Previously, the projects depended on the detailed knowledge of a few developers. These ‘heroes’ had significant influence in the development because their superior knowledge and experience made them very special for EC. Heroes, such as Raphael, were able to cope with various technical setbacks throughout the system development. Research participants reported a change in the way of communicating and team working. Communication paths have lengthened and decisions need more time. The team of developers with diverse tasks and responsibilities was divided into four different departments, such as software and hardware development, system tests, and project management. In conjunction with this, the teamwork altered in the way that the number of overtime, late shifts, and social activities not related with work decreased over time. Martin stated:

“These changes were beneficial for my work because nowadays the activities are more structured. Before that, the decisions where based on talks in passing. This uncertainty was overcome with schedules, sophisticated documents before the technical preparation starts, and just better organizational efforts.”

5. Analysis

The analysis highlights the complex dynamics of managing an embedded system development project. In particular, the following aspects of project management of embedded system development became apparent: changing organizational circumstances, evolving processes, influential developers’ social context, and interacting influences on project management.

5.1. Changing organizational circumstances

It was evident that there was demand for sophisticated technical solutions in the realms of hardware (multiprocessor platform) and software (hardware platform and client software). In addition, the development was affected by several uncertainties, such as ambiguous and fluctuating requirements. However, the hardware and software issues provided not only technical problems, but the changing organization influenced the project management of Mem-Beth significantly. Previously, the few project members were more or less engaged with multidisciplinary activities. After reorganization, the project members were split into specialized departments with task differentiation, such as hardware development, software development, quality surveillance, and project management. Gabriel and Michael explained that some overlap of tasks could not be avoided, such as testing the system quality and software quality. In addition, an important factor of managing an embedded system development project was the product strategy. The significance of this project enhanced over time, because of the increasing demand for more devices than expected. As
described in the case study, the project had to be restructured to satisfy this need. So, managing the project of embedded system development is complex and requires intense efforts of all project members.

5.2. Evolving processes

It was also evident from the case study that besides changes to the organizational structure, the usage of processes differed over time. During the initial phase of Mem-Beth, improvisation and bricolage were strongly practiced to cope with technological uncertainties. The project manager agreed with these improvisational and bricolage activities by developers but tried to set limits to chaotic approach to unscripted processes. The involvement of improvisational and bricolage actions was a common behavior during development, although these situated activities might appear as lacking in conciseness to outsiders. Later in the development process, some of these processes became best practices as well as organizational standards. Although these processes were improvisational and bricolage actions, project members agreed in its usage, because developers and the project manager followed them over time. In addition to these organizational standards, the project management involved more sophisticated planning, such as detailed project schedules, product releases and sophisticated system tests. As described in the case study, there were informal processes important for the project management. These informal processes helped the developers and the project manager to provide ‘hospitality’ towards technology in order to cope with uncertainties. The contribution of the structured process management framework was the detailed regulations at the organizational interface for procurement and documented meetings with other organizations. Besides these concerns, the developers as well as managers tended to ignore the formal standards during their day-to-day work. This caused challenges within the organization. Many organizational actors who were not involved with project Mem-Beth expressed their concerns.

5.3. Influential developers’ social context

Another interesting aspect of this case study is the intricacies of the developers’ social context. The various technical specialists facilitated the development. However, the project management in general and the interaction between developers and the project manager was more of a balancing act. The continuous bricolage and improvisational activities from the developers hindered the efforts of the project manager. However, a form of understanding of the technology evolved between the developers and the project manager, particularly during the critical initial phase of Mem-Beth, when the developers and project manager worked overtime in order to overcome the technological challenges as described in the case study. The project manager was respected as a core member of the team, because he provided the domain knowledge in that development and he placed emphasis on the need of the customer in order to avoid any over-engineering of the device and its software. When the various departments became more defined, the project managers were in a different office, hence their day-to-day interaction with the developers decreased. Although from time to time there were some events for socializing, the closeness between the project managers and developers were lost.

5.4. Interacting influences

Many influential factors on project management in an embedded system development became visible, such as changing organizational circumstances, evolving processes, and an influential developers’ social context. Clearly, these factors influenced each other. In addition, these interacting influences may have been affected by the efforts of EC organizational leaders and Mem-Beth project leaders, to comply with formal standards, such as the structured process management framework of ISO 9001. So, these interacting influences led to a transformation of the previous developers’ social context towards more structured setting improved the predictability and benefited the project management.

6. Discussion and implication

6.1. Unfolding planned activities

The theoretical background of this research provided two seemingly contradicting sets of project development and management styles. The analysis of this case study highlights the progress from a more emergent toward a more planned style. Previously in this project, activities of the project managers and the rules and standards of the organizational ISO 9001 where not elaborated enough to cope with the complex undertaking of embedded system development. The activities of project managers and the organizational ISO 9001 rules and standards
might have been undermined because improvisation and bricolage activities were common practice. The distinctive departments were not clearly defined, so the people who were involved with project work (developers and the project manager) participated in the shared actions and practices of the developers’ social context. The project managers and developers enjoyed the emergent project development and management style because it had been part of the organizational culture. Over time, the organization needed to adapt to new circumstances such as dealing with an increase in unit volume and the organic growth of the entire organization. In addition, the organizational leaders required higher certainties in managing Mem-Beth, because the risks with higher unit volume production might be higher than in low unit volume production. Best practices and principles were welcomed by the developers and project manager and then became informal rules and standards. These rules and standards formed structural framework, which was helpful enough that the project manager was able to cope with surprises throughout the project. In other words, the structural framework enabled the project manager to plan activities. Moreover, the compliance with the official structured process management framework (ISO 9001) was limited. Only absolutely necessary issues were established, such as the communication toward other organizations and procurement. Many organizational ISO 9001 standards, such as reviews, early tests, and documented working, have not been followed.

Figure 1 draws on the analysis and depicts the interplay of emerging and planned project management in the embedded system development context. The cloud around the project management symbolizes the crudeness of emergent project management practices during the initial phase of project Mem-Beth. The square-edged box depicts the mature application of project management activities as observed in the latter stage of Mem-Beth. The two arrows point out a continuous process between the contrasting project management types. As the more planned style of project management becomes established, it loses its ability to cope with the complex embedded system development. So, the cycle continues with the continued emergence of more improvisational acts and subsequently these improvisational and structured processes become more formalized with their recursive practices over time.

At this point, we may elaborate on the phenomenon of this transformation of project management activities. In this case, the developers and the project manager were engaged in the particular context of embedded system development. Although the social context of the developers influenced the activities of developers and project manager significantly, the capabilities of them nurtured the reliance upon informal standards. This relates to the power vested in the individual developer or project manager – Giddens’ [28] ‘agency’. The specific behavior or activities in which humans engage was guided by the rules and resources in which social interactions take place [28].

This capability and power of transforming the social context of the developers might also be influenced by the reorganization. However, the individual understanding of developers and project manager inspired them too. By doing so, the developers and project manager enriched their interactions with more planning activities, although improvisation and bricolage activities were involved as well.

6.2. Implications

The approach we described in the theory section which highlights the values of care, hospitality, and cultivation for a better comprehension of system
development may sound contradictory to the planned methodologies, but they do provide some interesting ways to understand embedded system development better. Particularly in research settings, where improvisational and bricolage activities are observable, this comprehension approach might be of value.

Furthermore, a critical understanding of formal structures could encourage standards, be they informal or formal. The value of methodologies might be more important in more predictable environments. In our opinion, the contribution of ISO 9001 is limited, if improvisation and bricolage activities are likely to be a daily occurrence. This limitation is natural, because the background of ISO 9001 was the standardizing efforts of manual tasks by managers. In contrast, creative tasks tend to relate to specific situations, which are less easy to standardize. However, fairly advanced projects involve a better understanding of the environmental variables. So, a solid set of best practices, techniques and procedures might be of advantage for project management. It may involve flexible standards that reflect the situational project demands.

We should not disregard the influence of the project manager, because the transition of the planned and emerging project development and management style is not an issue of situational leadership. The transition might be sizable and important and lasted in this case study, over a much longer period.

By drawing on Ciborras’ [24] values of care, hospitality, and cultivation, we may derive another theoretical aspect from figure 1. The transformation of project management in the embedded system development context results in various attributes of project management. For example, the connection between developers and project manager eroded as the organization started to grow organically and separated the project members into various departments, and the more planned style of project management became apparent.

We imply for practice that embedded system development projects might be manageable through improvisational and bricolage activities. In this case study, the project manager and developers tinkered with available items and resources in order to overcome the difficulties of a turbulent environment and an inappropriately structured process management framework. These emergent activities matured over time, so that previous improvisational and bricolage practices became predictable techniques. They may provide a relevant coping strategy especially for technical issues. Continuous use of similar improvisational and bricolage activities might be elaborated as best practices in a particular context. By using again these best practices, they may emerge as new standards.

7. Concluding remarks

This study is a contribution to the discussion of emerging project development and management styles. The research setting provided an interesting context for a complex task of project development and management. We tried to understand the developers’ and project managers’ perceptions of various actions throughout the project. The research provided insights into changing organizational circumstances, evolving processes, and an influential developers’ social context. An important feature of this case study was the continuous improvisational and bricolage activities by developers and project manager that lead to a smooth transition of the organization. The structured process management framework of ISO 9001 had insignificant influence on project members. This phenomenon was investigated in other settings also (e.g., [34]). However, the embedded system project development provided a context to deal with challenges. Hence, the interacting influences on that setting provided an interesting environment to examine an empirical study of Ciborras’ [24] approach to understanding system development. The findings of this paper might be applicable not only in the management of embedded system development, but also in other similar project management settings.

8. References


