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Best Practices for Managing the Fuzzy Front-End of Software Development (SD): Insights From a Systematic Review of New Product Development (NPD) Literature

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ABSTRACT

Although they have followed independent paths of development, the two fields of software development (SD) and new product development (NPD) face common problems (Buyukozkan and Feyzioglu, 2004; Shane and Ulrich, 2004) and share many similarities (Nambisan and Wilemon, 2000). The research findings in the NPD domain are therefore relevant to SD (Nambisan and Wilemon, 2000). In this article we conduct a systematic literature review to identify the empirically validated best practices in the fuzzy front end (FFE) phase of NPD. The findings presented in this article will be useful as any improvement in the upstream front end phase of SD can result in the most positive impact on downstream SD activities (Hannola, Oinonen and Nikula, 2011).

Keywords

Software development, new product development, fuzzy front end

INTRODUCTION

The FFE, a term first popularized by Smith and Reinertsen (1998), is the period in the NPD cycle between the time a new product idea is conceived and the time its business value is evaluated (Kim and Wilemon, 1999). The front end stage is complete when the business unit takes a go/ no-go decision with the business unit either committing to fund and launch the new product development project or deciding not to do so (Khurana and Rosenthal, 1998).

In this systematic literature review we examine existing NPD literatures to investigate what SD can learn from FFE (Fuzzy front End) best practices in the non-software product domains. Software industry is relatively new. The other industries have been around for a much longer time. Learning from the best practices in other product domains can therefore result in accelerated learning for SD. Among other non-software product domains there is a long tradition of sharing and learning from each other. It is therefore imperative that SD also benchmarks its practices with those of NPD practices in other product domains and adopts those that are likely to provide maximum benefits.

Studies have shown that managers of successful products invest considerably more money and effort on FFE than managers of less successful companies (e.g. Kim and Wilemon, 2002). Organizations that succeed in innovation are those that excel in managing the FFE phase of NPD (e.g. Cooper, 1998; Dwyer and Mellor, 1991; McGuinness and Conway, 1989). According to Khurana and Rosenthal (1998) “the real key to product development success lies in the performance of the front-end activities”.

Literature relating to the fuzzy front end is expanding (e.g. Koen et al., 2001; Reid and de Brentani, 2004) and acceptance of the importance of the fuzzy front end is increasing. Smith and Reinertsen (1998), who coined the term, argue that the fuzzy front end is often lengthy, poorly understood, and full of opportunities for improvement. Kim and Wilemon (2002) argue that one of the most important and difficult challenges facing managers is effectively managing the fuzzy front end of the NPD process.

FFE can help organizations with achieving the following objectives: the selection of the right product; the creation of a clearly-defined product concept; an efficient new product selection process; and the development of effective teams within and beyond the FFE phase (Kim and Wilemon, 2002). As very little academic work has been done on FFE in software engineering and IS (Information Systems) disciplines, the FFE best practices from other product

disciplines will provide useful insights to software development organizations in the areas of generating and capturing innovative project ideas, creating a clear business case for promising projects and selecting the right projects that will meet the organization's business objectives. In this study we scan non-software NPD literatures to identify only those best practices that have been empirically validated and have resulted in improved FFE performance.

METHOD

A systematic review methodology (Kitchenham and Charters, 2007) was used to search and evaluate all available research that relates to FFE best practices. Before conducting the systematic review a formal review protocol was developed that included:

1. Research Objective

To extract the various empirically assessed NPD best practices that result in improved performance of FFE and examine their relevance to SD.

2. Search terms

The research objective had the following key words:

“New Product Development”, “fuzzy front end”, “best practice”, “empirical”

Other related words and synonyms identified are:

“fuzzy front-end”, “good practice”, “survey”, “experiment”, “case study”, “case-study”, “survey”, “experiment”, “case study”

The following search string was used:

("new product development") AND ("best practice" or "good practice") AND ("fuzzy front-end" OR "fuzzy front end") AND ("empirical" OR "survey" OR "experiment" OR "case study" OR "case-study")

This search term was modified to the requirements of the databases.

3. Resources searched

The primary search process involved searching following databases using the keywords in the search term section above:

- IEEE Explore
- Science Direct
- ACM Digital Library
- Compendex
- Google scholar

4. Document Selection

In the trade-off between rigor and comprehensiveness we chose rigor and included only those articles that were published in peer reviewed journals and conference proceedings. As we selected articles only from peer reviewed journals and conference proceedings, we did not specify our own quality criteria.

Inclusion criteria

1. Directly addressed the research objective
2. Articles published in peer reviewed journals and conference proceedings
3. Empirical studies

Exclusion criteria

1. Papers in languages other than English

5. Paper selection process

The following steps were followed for paper selection::

1. In the first stage the articles were extracted from the databases based on the search string
2. In the second stage duplicate articles that were extracted from the databases were removed
3. In the third stages irrelevant papers were manually identified and excluded based on the titles.
4. In the fourth stage the abstracts were analyzed and only those papers that assessed the best practices empirically were selected. Theoretical models and conceptual studies were excluded
5. Full text of the shortlisted articles was read quickly in the third stage to assess whether it meets the defined criteria for inclusion in the systematic literature review. References were checked to determine whether relevant studies were missed in the primary selection process. The main reason why some of the articles were missed was because of the use of hyphen, for example case-study. The search string was modified to include additional key words with hyphen and Steps 1,2,3 and 4 repeated.
6. At each stage the second author validated 20% of a sample of the selections. In case of conflict the third author will be brought in and the majority opinion taken if consensus could not be achieved.

6. Data Extraction Strategy

The references for each study were recorded using EndNote. Data from studies that addressed the research objective was extracted using the standard data extraction form (Appendix I).

RESULTS**Search Statistics**

Serial Number	Resource Searched	Number of Articles
1	IEEE Explore	0
2	Science Direct	163
3	ACM Digital Library	0
4	Compendex	0
5.	Google scholar	22

Table 1: Total number of articles found in each resource

We searched IEEE Explore, ACM Digital library and Compendex primarily to check if there are any articles related to FFE practices that have been referred to in the computing discipline. However we did not find any such articles in these resources. All the articles were located in Science Direct and Google Scholar. The reason for this could be the lack of research in the FFE phase of SD compared to the FFE phase of NPD in non-IS product domains.

Serial Number	Selection process	Number of Articles
1	Papers extracted from databases	185
2	Papers after duplicates were removed	177
3	Papers selected based on the titles	124
4	Papers selected based on abstracts	64
5	Papers selected based on full text scan	38
6	Papers rejected/ added by independent researcher	0

Table 2: Number of articles selected at each stage of the selection process

All the 38 papers selected for the study were empirical studies, of which 21 were surveys, 16 were case studies and 1 was a qualitative study.

Organization of Results

From the articles shortlisted for systematic literature review, we listed the best practices that were found useful for FFE performance. There were differences in nomenclature used for the same practice across studies. For uniformity and coherence we put similar best practices under a common label. From our study we could identify 10 empirically validated best practices. The practices are not listed in any particular order. Therefore the relative importance of these practices should not be derived from the sequence.

IDENTIFIED FFE BEST PRACTICES

Of the 38 empirical studies the findings of 3 studies did not support the relevance of NPD best practices for performance improvement of the FFE process. Of these 3, 2 studies (Maffin and Braiden, 2001; Oliver, Dostaler and Dewberry, 2004) found the relevance of using the best practice to be dependent on organizational and national context, while another (Loch, 2000) recognized the fit between NPD strategy and corporate goals to be more important for FFE performance than adoption of best practices. The remaining studies found best practices to be relevant for improving the performance of FFE phase of NPD. We first list the identified FFE best practices below in the non-IS domain below and then discuss their relevance to IS in the discussion section.

1. Innovative Organization Culture

NPD is all about innovation and creativity. Of the various phases in the NPD cycle the FFE is the phase that captures and generates maximum innovativeness. It is at this stage that the new product ideas are generated and evaluated. Although innovativeness is required in later phases of FFE, the majority of development efforts in post FFE phases are expended in implementing the new product concept identified and developed during the FFE. Therefore creating an organization culture which is conducive for innovation is particularly critical for FFE performance (Langerak et al., 2004a; Kim and Wilemon, 2002b).

The elements of innovative organization culture include not only recognizing and rewarding employees for outstanding new product ideas but also encouraging risk taking behaviors (Kim and Wilemon, 2002a,b). Product failures should not be condemned but should be accepted and treated as a learning opportunity (Rosenau, 1988; Kim and Wilemon, 2002a,b). A survey of Taiwanese high-tech firms (Ho and Tsai, 2011) to measure the business impact of innovative culture found innovative culture to have a strong positive effect on FFE performance.

2. Formal FFE Process

In their study Khurana and Rosenthal (1998) found two workable models for FFE. One model views FFE as a process, while the second model suggests an emphasis on culture. The process model was found to be more prevalent in the U.S. and Europe, while the culture-driven, consensus-based, informal style was found to be more prevalent in Japan. However, Khurana and Rosenthal (1998) suggest that for evaluation of options and trade-offs in

FFE a certain acceptable level of formality and process-orientation is required. Decisions made without formal objective evaluation criteria are likely to rely on subjective evaluation and gut feel. This is risky as all subsequent phases and development activities are dependent on the quality of decisions made in the FFE

In their case study Montoya-Weiss and O'Driscoll (2010) found that at Nortel, the front end of the NPD process was unstructured and ad-hoc. The article then describes how Nortel improved its FFE performance by developing formal idea development, idea evaluation and idea filtering processes that leveraged the company employees and market information to provide a consistent and structured approach. These processes were then implemented using electronic performance support system (EPSS) technology. Nortel's front-end process and EPSS application provides a good example of how the fuzzy front end of NPD can be made less fuzzy and more manageable (Montoya-Weiss and O'Driscoll, 2010) through a formal process.

3. Strategic goals

The outcomes of FFE should match the strategic goals set by the organization. The absence of strategic goals or lack of knowledge about the strategic goals of the organization could lead to lack of direction and misalignment of efforts (Bonner, Ruckert and Walker, 2002). Smith and Reinertsen (1998) found that strategic goals helped the organization develop FFE capabilities that met market requirements. Formulation of strategic goals has been shown to result in higher FFE performance, particularly for unstructured tasks (Kim and Wilemon, 2002a). In their survey of Taiwanese high-tech firms, Ho and Tsai (2011), found that setting strategic goals has a strong positive effect on FFE performance. However another study (Tarafdar and Gordon, 2007) found that performance is likely to be more positively impacted on the fit between strategic goals and capabilities than merely on formulation of strategic goals.

4. Cross-functional Organization Structure.

Organizations have a choice to either use a functional structure or a cross functional structure. Each structure has its advantages and disadvantages. Functional structures promote specialization while a cross functional structure promotes organization wide collaboration. In FFE there is a need for multiple skills to be utilized in making complex decisions about technology, markets, financial viability and manufacturing issues, thus entailing a cross functional team structure (Griffin, 1997; Ernst, 2002; Lee and Chen, 2007; Garcia et al., 2008). This is especially so in case of disruptive innovations where there is a high level of internal and external uncertainty and where specialized inputs are required (Olsen et al., 1995; Song and Xie, 2000).

In a survey study of 155 US firms, deVisser, Weerd-Nederhof, Faems, Song, BartvanLooy and Visscher (2010) found that organizations that use cross-functional teams for their disruptive NPD process show significantly higher levels of FFE performance than organizations that use a functional structure. However organizations that use a functional structure for their incremental NPD process show significantly higher levels of FFE performance than organizations that use a cross- functional structure for their incremental NPD process.

5. Information Management

The success of the FFE phase is characterized by its ability to manage large amounts of different types of information, from different sources, to make complex product decisions (Zahaya, Griffin and Fredericks, 2003). The data may be qualitative such as customer feedback or it may be quantitative such as estimated product costs. To evaluate the product opportunity correctly organizations need to ensure that all team members of the FFE process are on the same page with all the different types of information. If the information is not comprehensively collected and accurately disseminated among team members it may lead to project failure at later stages in the project lifecycle (Sherman, 2000). Use of IT tools was found to significantly improve the information management in FFE process. Although the tools varied in their effectiveness overall the use of these tools was found to improve FFE performance through greater efficiency of information management (Durmuşoğlu and Barczak, 2011; Kohn and Hussig, 2006).

6. Shared product mission

FFE team members come from different background and have different perspectives on NPD issues. A shared project mission provides the team members with a common goal and understanding of what they are trying to

accomplish. It facilitates resolution of disputes among team members, establish priorities and make trade-off decisions. In a survey administered to 3000 professionals involved in NPD, Rauniar and GregRawski (2012) found that shared product mission reduced product bottle-necks and enhanced overall FFE performance. With a shared project mission, team members were found to be more receptive to each other and collaborate to generate a larger pool of innovative ideas (Atuahene-Gima (2003)

7. Clear product targets

Setting and communicating clear product targets in terms of Quality, Cost and Schedule helps team members to work collaboratively in achieving the overall product mission. It helps the project team members in making trade-off decisions between Quality, Cost and Schedule (Rauniar et al., 2008a), identify opportunities and provide the best design solution under given constraints (Enright, 2001). Teams that work coherently were found to have a clear grasp of product goals (Larson and LaFasto, 1989). Absence of unambiguous product targets lead to lack of involvement (Katzenbach, 1998) and lingering disputes (Amason, 1996). Having clear product targets from the early FFE stage is crucial for improving time to market, collaboration among team members and process and product performance (Murmann,1994).

8. Out of sector knowledge

FFE teams continuously capture knowledge from both internal and external sources. One source of external knowledge is benchmarking partners, among which the out of sector partners can contribute more for increasing innovation in NPD. The benefits of in-sector knowledge sharing between firms are limited due to the potential of sharing competitive advantage. In their survey Mcadam, O'hare and Moffet (2008) found that out of sector knowledge is very effective in promoting innovation.

9. Manager knowledge of decision biases

In the FFE stage of NPD there is uncertainty and information available is incomplete. Managers often make subjective decisions and use gut feel under these constraints. This problem is compounded by the fact that psychological biases such as hindsight, framing, attenuation and anchoring are quite common (Jansson and Smith, 1991; Hammond et al., 1998; Gilovich et al., 2002; Keeney, 2004). As a result the decisions taken in the FFE stage of NPD may not be rational. This affects the quality of decisions made. Good innovative product opportunities may get overlooked and average products may receive preference. However instead of attempting to remove the managerial biases, a more practical approach is to increase the managers' awareness about these biases (Keeney, 2004) . In their case study of a Swedish automotive company, Kihlander and SofiaRitze'n (2011) found this approach to be very effective in managing decision biases.

10. Heavy weight product manager

A heavy weight product manager is one who has both formal and informal influence over his team members. He reports to senior management for the product outcomes and is able to effectively coordinate product development across functions (Wheelwright and Clark, 1992). Typically he has a senior rank within the organization and has considerable expertise in his domain (Schilling and Hill, 1998). In their study of 3000 professionals involved in NPD, Rauniar and Rawski (2012) found that having a heavy weight project manager at the early stages of NPD such as the FFE stage helps in establishing cross functional teams and creating powerful product concepts and plans.

DISCUSSION

With soaring IT budgets and increasing competition in the market place, software organizations, whether they are developing software for the organizations' internal use or developing software products for the markets, should be aware whether they are investing in right projects. Managing the FFE phase is therefore critical for software development.

In this study we identified the FFE practices prevalent in non-software product domains through a systematic review of NPD literature. The empirically validated practices are compiled and described in the article. Bringing the learnings from a parallel stream of literature is a promising approach as something special and important takes place during the innovative idea formation stages of NPD. It brings together employees with different skills and across

departments to deliberate on new ideas and develop a business case. This enables organizations to not only make an informed decision on which new products to invest in but also in the creation of a clearly defined product concept and development of effective teams within and beyond the FFE phase.

FFE is time consuming (Gümüşkaya, 2005). It's not uncommon for a project to spend months or years in FFE and then to come up a crash development schedule to make up for lost time. It's may be easier, cheaper and less risky to improve performance by saving time in FFE than it is to compress a development schedule by the same amount. The implication for SD is that it will increase the chances of developing good quality software which is relevant to the business needs of the organization.

The 10 best practices offer SD activities to improve on multiple fronts through the FFE phase. Software systems are transforming organizations and the way they perform tasks. The more innovative the software application the greater the value that is derived through novel and more efficient business processes. For this an *innovative culture* is essential. Also since business processes are now cutting across functional barriers *cross functional collaboration* is becoming increasingly important. The reengineered business processes through development of innovative software applications must be aligned to meet business goals. Even the most innovative software will not have much value if it is at cross purposes with the organizations' business goals. Therefore it stands to reasons that the practices identified such as an innovative culture, cross-functional organization structure and *alignment of FFE strategies to business goals* have value for software development organizations.

Further the identified best practices suggest ways in which cross functional collaboration, which is vital for successful identification and development of innovative software applications, can be improved through practices such as having a *common product vision* and *setting clear product targets*. . For successful implementation of innovation processes the best practice recommended is the deployment of a *heavy weight product manager* to create powerful product concepts. For selection of right software projects the identified practices underscore the importance of *information management* and ways to avoid *psychological biases of managers*.

However, the suggestion is not to adopt the practices as a complete set but select those that are relevant to the organizational culture and the context of SD. For example a *formal FFE process* may work more successfully in organizations with a command and control culture rather than organizations with collaborative work culture. A *cross functional organization structure* may be more relevant for identifying software projects/ products targeting disruptive innovation rather than incremental innovation. Also, some practices may work well when other practices are also simultaneously implemented. For example, *innovative organization culture* may work best when the selected projects/ products are aligned with organization's *strategic goals*. Even the most innovative projects if not aligned with the strategic goals may result in waste of organizational efforts and resources.

CONTRIBUTION

To the best of our knowledge this is the first study to compile and consolidate the best practices in the FFE phase of new product development. FFE phase is recognized as being critical not only for NPD success but for overall business success of an organization. Our findings from systematic literature suggest that most studies see benefits in adopting best practices for effectively managing the fuzzy front end phase of new product development (NPD). The identified best practices have been empirically validated in the studies selected for review. Software developers can take cognizance of these proven best practices for improving the FFE which is recognized as one of the most critical phases in developing good innovative software aligned to business needs.

LIMITATIONS AND FUTURE RESEARCH

Although the studies included in the article have been through a thorough screening process, many of the included studies are based on a convenience sample. Also, some of the identified practices have been validated only in a single empirical study. For the sake of quality and rigor we choose only peer reviewed journals and articles published in conference proceedings. Thus in the trade-off between comprehensiveness and rigor we sacrificed comprehensiveness. This strategy may have resulted in "publication bias", that is there is a chance that a preponderance of studies selected for the systematic literature review are those that have positive empirical results. Hence some level of caution should be applied before fully committing the organization to these practices. In spite of these limitations this systematic literature review opens up avenues for investigations in the FFE phase of software development. By highlighting the importance given to FFE in non-software product disciplines and the

relevance of FFE for software development it is hoped that this study will stimulate conceptual and empirical work in the area. To begin with, future research can empirically validate the relevance of the identified 10 best practices in developing superior software application and products.

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APPENDIX I

Data Extraction form

Data Items	Description
ID	Unique identifier or the reference number for a paper
DOI/ URL	Digital Object Identifier or Universal Resource Locator
Bibliographic	Author, year, title, source.
Type of article	Journal/conference/technical report/workshop/book chapter/dissertation
Study Aims	The aims or goals of the primary study.
Context	Research area(s) the paper focus on.
Related papers	Short references of closely related papers.
Methodology	Qualitative / Quantitative / Mixed
Method used	In-depth interview, Focus groups/ Observation/ Survey/ Case study/ Experiment
Type of Study	Conceptual, Theory building, Controlled experiment, Survey, Case Analysis
Study Findings	Summary of major findings from the study relevant to the study objective/ s
Reviewer ID	The researcher or external person who reviewed the study