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Challenges in the Fuzzy Front End of the Production Development Process

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Abstract. As the demand for customized products increases, manufacturing industries are forced to adapt to rapid changing requirements in product demand by continuously developing new innovative and changeable production systems. In the early phases of production development, there are uncertainty aspects that needs to be managed until freeze of product design and development of a suitable production system. This front end is commonly considered as fuzzy since there is a lack of a structured production development process that supports the uncertain and iterative work that is required to develop feasible production systems in early phases. By identifying these challenges in the fuzzy front end of production development it is possible to inhibit future disturbances in the rest of the process and to increase future production system performance. In the literature, challenges in the latter part of the production development process has been thoroughly examined. However, few empirical investigations have explored the fuzzy front end in production development. The purpose of this study is to investigate challenges in the fuzzy front end of the production development process, focusing on new or comprehensive production system changes. To study these challenges, a multiple case study with 4 cases has been conducted. The empirical investigation consists of 5 semi-structured interviews and 5 participant observations. The findings show multiple challenges closely connected to project pre-conditions and organization structure related factors. Various project uncertainties in this early phase entails challenges to determine valid project objectives, scope and KPIs. Moreover, estimating the right amount of time and resources needed. Complex organization structures may have a significant influence on the way of working resulting in slowness in decision making. Furthermore, various communication challenges are identified which are mainly connected with the incapacity of including all stakeholders early in the development process.

Keywords. Fuzzy front end, challenges, case study, production development, manufacturing industry

Introduction

Intense competition worldwide drives manufacturing companies to continuously create and maintain competitive advantages. Multiple challenges for manufacturing companies emerges in this new unprecedented landscape of one fierce competition [1]. Increasing demand for new and customized products put pressure on manufacturers to become more innovative and changeable. The increasing number of variants to be

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produced in the same production system results in increased complexity, smaller product series with shorter life-cycles and lead times [2, 3]. Therefore, developing new production systems, or making comprehensive changes in current systems, is a necessity for manufacturers in order to stay competitive [4, 5, 6].

At the beginning of a production development process, before any preliminary production system concepts are judged to be ready for development, the main focus is commonly on product development and the level of production integration is low since it is generally executed and controlled by R&D. The potential for being innovative is usually very high in early phases and there is a turbid process for idea generation [7]. It is in this early phase of the process that the greatest potential for dealing with the challenges in production development exists. Furthermore, it is important that these challenges are identified, overlooked and evaluated sooner rather than later in order to inhibit disturbances in the latter part of the process. However, due to the complexity at this early stage and at the same time allowing for innovation to manage some of the defined challenges, ad-hoc behaviour is not preferable, but unfortunaltly frequently applied, instead of following a structured process [8]. The absence of a predefined process makes it more difficult to identify and overcome these challenges [4]. The "fuzziness" in the front end in production development may have a substantial negative impact on the manufacturers ability to coordinate, manage and plan the entire process. Additionally, it may affect the way of handling quality issues and making improvements in the latter part of development [9]. Hence, there is a need to investigate the challenges in the fuzzy front end of production development for new or more extensive changes to the system. It is assumed in this work that the fuzzy front end in production development is the phase in which product development consider several alternatives for solutions and the related product structure is not frozen, allowing production development to influence the freezing of the product architecture, by considering several alternatives for the production system, prior to decision making and design freeze.

Previous research have mainly covered the fuzzy front end in product development and less research conducted in the fuzzy front end in production development [10, 11, 12]. There is a gap in literature covering the challenges existing in the fuzzy front end in production development [13]. Challenges occuring in the latter part of the process has been thoroughly examined [14]. The purpose of this study is to investigate challenges in the fuzzy front end of the production development process. In this research, the challenges in the fuzzy front end of production development are identified which could constitute as barriers in the process of establishing and achieving successful production systems, having a substantial negative impact on future production system performance.

1. Joint product and production development

Demands for new products and technology require manufacturers to be innovative in their product development process. But only those capable of converting these innovations and prototypes from idea to reality will profit from the inventiveness [15]. The process for manifesting the ideas is dependent upon a production system. However, companies have a tendency to not fully consider the manufacturing aspects for certain product concepts [16]. Product development and production is commonly organized in two different departaments and unfortunately the process for working jointly together in a common process is often lacking although the two processes are highly dependent on eachother. Often this results in prioritization of product development supressing the urgent need for integration with production development [7, 4]. Additionally, innovation becomes associated with product development rather than production development, even though it has been shown that a combination of both product and production innovation is a necessity when developing new products [17, 15]. Production innovation aims to derive efficiency gains through quality improvements, cost reductions and more stable processes which helps to reduce development times for products [18]. The development of a production process has been described in different ways by scholars, but one common description is development of the manufacturing process [19]. Included is the presentation and introduction of new input materials , new manufacturing technology and knowledge [8]. Product development and production development is usually carried out in sequential or partly parallell succession instead of exclusively in parallell, although several studies have shown that it could imply superior outcomes [20, 21]. The interface between production and product development is highly sensitive with many uncertainties. However, very interdisciplinary as well as dependent on eachother. To efficiently handle the transition from product to production development is considered complex but also a critical success factor. Several challenges could be managed in case successfully implemented [15].

2. Fuzzy front end in production development

The process for developing new production systems is commonly and preferably carried out by following a predefined process. By following a structured procedure, it is more likely to keep deadlines and not exceeding budget [4, 22]. Furthermore, it can help to achieve good process coordination, planning, and management [9]. However, in the early phases of this process it is hard to carry out the work in a structured manner. This early phases of production development can be described as first phases of a new manufacturing technology that starts with a demand and end when it has been proven that set requirements has been met [13]. Additionally, it has been described as the period from when an idea surfaces to when the results from that is ready for being transferred to production [10]. The early phase for efficient generation of new production system concepts, is highly dependent on well defined objectives, including key functionalities and constrains [8]. The commonly high uncertainty level in this phase needs to be managed in a structured manner, but this cannot be done with detailed processes or a detailed plan. Since this process is usually dynamic and iterative, it needs to be managed by focusing on key milestones and consider many alternatives that are developed in a cross-functional team, more in line with the agile development framework with sprints [23, 24]. However, this is ordinarily not the case partly since product and production development are not integrated and the budget and resources allocated to the fuzzy front end is limited. This imply that the tasks are carried out by one person or a smaller group in one department, not advocating cross-functional teamwork or aligning objectives [10]. The results are that the fuzzy front end of production development becomes associated with being technically difficult and time demanding allowing for other challenges to arise. Dealing with these challenges in an early stage is critical for gaining competitive advantages [8, 24].

3. Critical factors for achieving successful production development

The dynamic environment in the fuzzy front end could pose for challenges that needs to be managed in order to develop an efficient production system that fulfill all requirements [25, 13]. But determining the failure or success of a development process is more comprehensive and diffucult to assess since the perception of being successful may differ between e.g. client and top management. Two parties may have different ways of evaluating process success and, therefore, have different expectations for the project [26, 27]. In order to establish production development success in early phases, it is essential to align project expectations, goals and preferable outcome between all parties and to ensure that all in the cross-functional team have understood the project objectives [28]. By working in a joint effort to develop a common understanding for the key characteristics of the intended productions systems, and by identifying the key challenges, the project is more likely to succeed [22]. Furthermore, it is important to focus on developing several early concepts that meets the key functionalities and to ensure that there is a right combination of broad and detailed skills in the team [26, 25]. In this early phase, developing several concepts, parallell with product development concept development, parallell with product development concept development, working with trade-off curves and involving the entire team can help with efficient decision making [29]. Additionally, trying to visualize various concepts can help team members to evaluate concepts and focus on a robust concept with the intended flexibility [30, 28]. In order to manage this phase, visible planning could be a great support, as that help all to obtain a common view, but also allows for more people in the team to engaged and involved [27].

4. Methodology

An empirical study was conducted in order to investigate challenges in the fuzzy front end of production development that may have substantial negative impact on future production system performance [31]. The definition of production development in the study relates to the conceptual phase of the production system development process. The empirical data and information presented has been collected through a multiple case study including 4 cases in the manufacturing industry [32]. The cases represented 4 different stakeholders who participated together in one development project. In accordance with the topic of the paper the development project was in a very early phase during the study. At this stage the regular production development process or organisation was not involved. The stakeholders represented were one larger automotive manufacturer (A), one automotive industry supplier, first tier (B), one engineering consultant firm (C) and one independent development organization (D). Data was collected through semi-structured interviews and participant observations. The data consisted of results from 5 interviews with a total of 9 respondents representing the 4 different stakeholders. An interview guide was developed prior to the interviews and was formed in line with the framework for establishing critical factors for successful projects [27]. The interviews had a duration between 60-120 minutes each. The interview questions were open-ended questions which were directly linked to framework. In table 1, the case study information is summarized.

Table 1. Case study information

Case study	Role in project	No. of Interviews	No. of respondents in each interview	Respondents
A	Project contractor: Project implementation, coordination and management	2	1	Manufacturing research director, Research project leader
B	Supplier to project contractor: Developing new production solutions	1	3	Global project leader, New business and innovation manager, Quality coordinator
C	Contributing with consultants for production development	1	1	Department manager
D	Knowledge communicator towards industry	1	4	Research project manager, Industrial project manager, Communicator, Research communicator

Participant observations took place in the shape of the project meetings occuring once every month for 5 months. Each project meeting was between 2-4 hours long. For each observation the agenda of the meeting, stakeholders participating, problems needed to be solved and current barriers in the project was noted.

In this study the framework developed by Belassi and Tukel [27] has been used for identifying and classifying project success related factors. The data obtained from the interviews and observations was later transcribed and categorized into these 4 areas, based on and deriving from the framework [27] including: (1) Factors related to the project (2) Factors related to project manager and team members (3) Factors related to the organization (4) Factors related to external environment. The categorization was made to structure the data and see how it correlates to the critical success/failure factors in projects. This was done in order to unravel and clarify were the heaviest challenges lie. After the categorization, The results of the gathered data was later displayed in a matrix in order to show the concise delivery of what was analyzed [33]. The areas in the matrix are connected to the framework areas.

5. Empirical findings

The following findings are presented in accordance with the categories of the critical success factors for projects [27]. Statements (S) from the interviews and the observation results are classified into different numbers (XX), described as (S XX, O XX) representing various challenges identified. These challenges are later presented in Table 2 at the end of the chapter along with the challenge commonality which is marked as "Score" in the table.

5.1. Factors related to Project

Several critical challenges were identified which connected to various limitations in time and resources. One common discussion subject concerned difficulties when doing proper estimations of the amount of time and resources that would be needed in each activity during the development process (Statement I). The interview results indicate on a tendency among the respondents to overestimate time and resources available rather than the opposite, as stated by one of the respondents in case B; "In these early phases of a project we tend to overestimate our own capability and ability to deliver. The pressure from management is high and we would like to establish so much within a limited time. But this is necessary if we want to be innovative: better to test many ideas rather than few."

Four respondents experienced an overestimation of assets related to project uncertainties regarding: scope, objectives and key performance indicators in this early phase of development. It further caused miscalculations of these parameters which had to be adjusted in the latter part of the process. If not adjusted by project management, the project would be unfeasible (S II). Four respondents, representing larger manufacturing organizations, described an evident need for shorter lead times and an increased pressure from management to develop products within limitied time frames, at the same time as cutting costs. Two respondents further described that this hastens decision making, contributing to incorrect setting of objectives, KPIs and scope. One respondent claimed that it also inhibits the innovation ability (S III).

All the respondents except one experienced challenges when trying to find a standard work routine that could be applicable in every production development project. The common opinion was that it had to do with project uniqueness (S IV). Some suggests that larger projects have higher probability to deviate from a standard work routine since it has more cross-functional activities to consider and therefore harder to steer. Conclusively, 4 respondents suggests that this makes it harder for the project manager to plan, coordinate and schedule the project. Five respondents described that it is hard to view the resource consumption for larger projects (S V). The observations showed difficulties when specificing each activity and the content of that activity. It became evident that these difficulties increased when specifiying activities further ahead in the time plan. Although it was hard to specifiy the activity content, it was easier to delegate the right team/teams or person to the activity (Observation result 1).

Three respondents explained that it is not enough time and resources available in the project to begin with, provided by management. In this case, parameters are fixed and cannot be changed even if it would be needed in order to achieve project goal (S VI)

5.2. Factors related to project manager and team members

All the respondents discussed and indicated on difficulties to include all project stakeholders in the fuzzy front end of production development since the project is not set (S VII). Two respondents claimed that there is a problem with managing and maintaining a well established communication channel between the project manager, organization and stakeholders (S VIII). The observation results confirmed this statement, suggesting that the stakeholders create an advanced network with various organizational structures and routines, making it more difficult to establish a well working communication channel (O 2). Another contributing factor that may inflict on the communication challenges, shown in the observations, is that not all of the stakeholders and project members are participating in the monthly meetings (O3). Observation results also indicate on difficulties to integrate development phases and activities with each other, since different stakeholder often are responsible for different tasks and works seperately (O4). This was later confirmed by 6 respondents, explaining that information and knowledge transfer between different project teams and/or transfer from one phase to another repeatedly results in information loss, creating confusion among team members and employees (S IX). Furthermore, observation findings show that various stakeholders have different perception of different terms and statements allowing for different interpretation and understanding in various contexts (O5).

Four respondents explained that decisions are often based on experience and team members have a tendency to work in the same way for every project, which some suggests is making a project more sensitive when having new employees (S X). Additionally, it is explained that evaluations of previous projects and final solutions are almost non-existent (S XI). Allowing mistakes to be repeated, as confirmed by one of the respondents in case C; “ We are not good at following up previous projects and evaluating what we could have done better, and make those adjustments in the next project. We are actually doing similar mistakes all over again.”

Two interviews discuss the challenge for team members to have different responsibilities/roles in various projects simultaneously, affecting the sense of commitment for one project (S XII). As claimed by two respondents, resulting in lack of focus and engagement in the project.

5.3. Factors related to the organization

Three respondents discussed strategical communication with the management as an issue: bottom-up perspective (S XIII). Communication upwards was considered as challenging since it takes place in a limited extent and can be very though to carry out. One respondent, representing a larger manufacturing organization, asserted that this issue is closely connected to the organizational set-up, structure and decision model. The organizational structure is too complex and wast, induces confusion among employees regarding how to make decisions (S XIV). Furthermore, the respondent explain the troublesome and time consuming process with figuring out who is responsible for what and over whom. One respondent in case A claim that this results in slowness when taking decisions since there are too many routines to relate to (S XV); ”Decision models and structures are troublesome stories. First, it is extremely time demanding to figure it all out. Secondly, it is very common that we come across a halt in our process because of decisions that have to be approved by various people”. Seven respondents express difficulties with the project model used being to stiff, not being able to change or make changes in projects, resulting in an inflexible way of working not meeting customer demands (S XVI).

5.4. Factors related to external environment

The interview respondents barely discussed factors related to the external environment, in comparison with the other three areas. One of the respondents claimed that the external environment represents factors that are uncontrollable, it is not possible to influence or change them. Several uncertainties arises due to the impossibility to predict the future (S XVII) as stated in one interview in case A; “If the thunder destroys one of our facilities, or if our competitor comes up with a new, technologically advanced and highly competitive product, this is ofcourse a challenging situation. But it is how we react to those situations that decides the outcome. It is the result of our decisions that determines how challenging the situation is.”

Table 2. Challenges in the fuzzy front end of production development

Area	Statements/ Observation No.	Challenges	Score
Project	S I	Hard to conduct a proper estimation of time and resources that would be needed.	+++
	S II	Project uncertainties: objectives, scope and KPIs, leading to miscalculations.	+
	S III	Limitied time frame hasten decision making, inhibits innovation.	+
	S IV	Unique projects – no standard work routine.	+++
	S V	Hard to view resource consumption for larger projects.	+
	O 1	Difficult to specifiy each activity and belonging content.	**O**
	S VI	Lack of time and resources available in the project.	++
Project manager and team members	S VII	Not including all stakeholders early in the process.	+++
	S VIII	Not having a well established communication channel.	-
	O 2	Advanced network with various stakeholders with different organizational structures and routines.	**O**
	O 3	Project members not participating in monthly meetings.	**O**
	O 4, S IX	Difficulties to integrate phases and activities, transfer issues.	**O** ++
	O 5	Different interpretation of statements and terms.	**O**
	S X	Decisions based on experience – sensitive projekt.	+
	S XI	Lack of Follow-up and evaluations.	+
	S XII	Different responsibilities/roles, affecting sense of commitment.	-
Organization	S XIII	Limited strategical communication with the management.	-
	S XIV	Complex organization structure.	-
	S XV	Slowness in decision making.	-
	S XVI	Inflexible way of working – stiff project models.	++
External Environment	S XVII	Not knowing the future.	-

+++ = Discussed/shared with > 80 % of the respondents

++ = Discussed/shared with > 60 % -II-

+ = Discussed/shared with > 40 % -II-

- = Discussed/shared with < 40 % -II-

O = Observation findings

6. Analysis and discussion

Previous research has mainly covered the fuzzy front end in product development, while the fuzzy front end in production development has been neglected. The limited amount of existing research in this area has highlighted the definition and interpretation of the term along with its key activities [13, 10]. By presenting challenges in the fuzzy front end of production development, this research fills a gap. If notified and aware of these challenges, there is a greater possibility for being able to handle and overcome them, instead of becoming obstacles. The research presented in this paper is based on a multiple case study, consisting of four companies participating together in one development project. In order to increase validity this research should be part of a multiple case study including many different projects. This case study included four companies that had different sizes and organizational set-ups along with diverse type of markets and customers. Additionally, these companies had different roles and responsibilities in the project. This may have had an impact on research reliability since the interview questionnaire may have been interpreted differently among the interview respondents. Which was also partly shown in O5, the respondents had different interpretation of varrious statements and terms to begin with.

The analysis process was founded on the insight of Table 2 as being the valid core of the case study findings. The case study results were compared with previous research in order to see similarities and/or differences to find connections between the findings. The scientific contribution consist of additional knowledge for what the critical aspects are in order to execute a production development project in early phases in a efficient and predictable manner and thereby less fuzzy.

The case study results presented in Table 2, indicates that main challenges are related to limited time frames and lack of resources in the fuzzy front end of production development. This could demonstrate that production development in the fuzzy front end is not as prioritized, or integrated with product development, resulting in two separated processes allocating less resources to production development [10, 16, 20]. Subsequent consequences could entail for other challenges to arise since this part of the process becomes more time demanding as the technical difficulty increases [8]. Another high score challenge presented in Table 2 covered difficulties with integrating phases and activities, resulting in multiple transfer issues. It could be argued whether the process itself does not support or advocate cross-functional teamwork [10]. Possibilities to align objectives, or to develop a common understanding for the key characteristics of the intended productions system, would decrease which could affect project success [22]. The inability to align and share a common understanding would influence the communication capability, which was shown as multiple challenges in Table 2. The findings also indicate on several organization related challenges, first and foremost brought by complex organization structures, creating slowness in decision making contributing to a stiff and inflexible way of working. Difficulties with project models used being too stiff, not being able to change projects will represent as a major obstacle in this early phase of development. Since the process is dynamic, it cannot follow a specific plan but has to be more in line with the agile development framework [23, 24]. However, the case study results show that employees are commonly working and solving tasks from their own experience, which could make them more vulnerable for complete new changes, but arguably more flexible when sudden unplanned disruptions occur. This could be an advantage instead of disadvantage in the development process.

7. Conclusion

By developing new production systems, or making comprehensive changes in current systems, manufacturers can create and maintain competitive advantages and differentiate themselves from competitors. By identifying challenges in the early phases of production development it is possible to increase the future production system performance and inhibit disturbances in the latter part of the process. A multiple case study was conducted in order to investigate the challenges in the fuzzy front end of production development.

The findings show multiple challenges connected to project related factors, prominent are challenges with time pressure and insufficient amount of resources, which can inhibit the level of innovation. Furthermore, various project uncertainties in the fuzzy front end of production development makes it difficult to not only define the right amount of time and resources needed throughout the process, but to determine valid project objectives, scope and KPIs since the project is not set. This evokes further challenges with specifying the right content in each process activity and integrating the activities and phases with eachother. The findings also indicate on organization related challenges, first and foremost brought by complex organization structures, resulting in delayed decision making and contributes to a stiff and inflexible way of working. Moreover, identified communication challenges in the fuzzy front end of production development are very common and are strongly coherent with not being able to include all stakeholders this early in the process, affecting how the communication is carried out and managed throughout the process.

The findings presented in this research represent initial insights in challenges in the fuzzy front end of the production development process and the main focus has been on evaluation of a current situation. Future research should define models that are better suited to cope with these challenges than what has been current practise so far. Some approaches and methods that are applied in early phases of product development can also be considered for early phases of production development, such as part of the lean framework and agile principles [34, 35].

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