

What is Performance in Complex Product Development?

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The process of developing new products is one of the key business processes in a company, especially technology intensive ones. In order to continuously improve the capability of developing new products it is important to be able to measure the performance in the product development process. The dilemma though is that there are no good performance measurements available within complex product development. One reason, as argued in this research, is the lack of a holistic perception of performance within the development process. Data from an explorative five case study including 49 semi-structured open interviews regarding performance indicate that performance is perceived in terms of time, cost, and quality i.e., what is measured. Thus, in order to develop better measurements of performance, the perception of performance needs to be changed first.

To meet this need, a Product Development Organizational Performance Model (PDOPM) is proposed, consisting of three generic levels of activities: product strategy, project management, and product activities. These generic activities are modelled in accordance with the IDEF0 framework making it possible to conceptually reason about uncertainty, effectiveness, and efficiency at each activity level. Product development effectiveness and efficiency are also defined for the complete process. Further, product development efficacy is introduced to describe the capability of identifying or creating a market opportunity and being able to develop and deliver a product fulfilling exactly what was identified as the market opportunity.

1. Introduction

One of the key corporate activities to differentiate oneself from competition, thus forming a fundamental part of the core competencies of a successful company, is the process of developing new products and services. Today, the market is more competitive than ever (Goffin & Mitchell, 2005), thus, the demand for the product development (PD) process to continuously deliver sustainable value is greater than ever. PD is often organized in projects, which is suitable when a unique objective is to be achieved within a limited period of time. Traditionally, projects are evaluated using what is called the iron triangle or the triple constraint of quality, time, and cost.

In a recent study within a utility company, 72 percent of the PD projects failed against at least one of the goals of quality, time, and cost (Larsson et al., 2008). But

surprisingly, 82 percent of the projects still ended up being financially successful. This interesting finding illustrates the weak link between what is measured in a PD project and how successful the developed product will become. *What gets measured gets done* (Peters, 2002) and *you are what you measure* (Hauser & Katz, 1998) are two well known statements related to the use of measurements. Thus, if quality, time, and cost are the focus of the measurements, it may also be the only dimensions being managed.

In the literature, both within performance and PD, there is confusion in terminology. This may be the result of two research areas attracting scholars with various functional backgrounds. In a review of the PD literature (Krishnan & Ulrich, 2001), at least four common perspectives: marketing, organization, engineering design, and operations management were argued for. Moreover,

to describe the process of developing new products, various terms like product innovation, innovation, engineering design, NPD, R&D, and PD are used. In this research the term PD is adopted to holistically describe the process of developing new products in a company, by proposing the following definition:

“Product development is the set of activities beginning with the tools and processes used to perceive a market opportunity and ending in the production, sale, and delivery of a product fulfilling that market opportunity.”

The proposed definition is an extension of the one argued for in (Ulrich & Eppinger, 2003).

Performance measurement is also a diverse subject, including researchers with functional backgrounds as varied as accounting, operations management, marketing, finance, economics, psychology, and sociology all actively working in the field (Neely, 2007). A vast amount of research is also available within performance measurements and PD. Still, few studies analyze the PD process from a performance measurements system perspective (Jiménez-Zarco et al., 2006).

Performance is often associated with effectiveness and efficiency. However, there are several different interpretations of effectiveness and efficiency in the literature. According to (Neely et al., 2005), effectiveness refers to the extent to which customer requirements are being met, while efficiency is a measure of how economically the firm's resources are used, when providing a given level of customer satisfaction. In (Sink & Tuttle, 1989) effectiveness is described as doing the right things at the right time, with the right quality. Efficiency is similarly described as doing things right, often expressed as a ratio between resources expected to be consumed and resources actually consumed. These examples clearly illustrate the diversity in the present terminology associated with performance. Moreover, PD is more difficult to measure than other business processes e.g., due to non-programmed decision situations and uncertainty. It is therefore not surprising that there are no broadly accepted performance measurements as there are for other business processes, e.g., manufacturing (McGrath & Romeri, 1994).

Since the area of performance and PD is a relatively young research area, it is natural that a common body of knowledge is missing. Hence, further research with a holistic perspective of performance in the PD processes is needed. The objective of this research is to explore how PD performance is perceived within the industry and to initiate a discussion of what performance in a complex PD context is. The outline of this paper is as follows. In Section 2 the methodology used in this research, including an explorative multiple case studies, is briefly presented. Further, in Section 3 a previously developed model of performance is presented and this model is used to analyze the perception of performance within complex PD identified in the case study. In Section 6 the term PD efficacy is introduced to holistically describe performance and the research is ended with conclusions and discussion in Section 7.

2. Methodology

To deal with the complexity of PD, a systems theory combined with an actors' approach has been adopted, in accordance with the views of (Arbnor & Bjerke, 1997). Increased complexity stresses the need for models that can be used by teams to develop a shared understanding (Katz & Kahn, 1978). Systems theory is a promising effort to deal with this problem, where an understanding of a system can not be based on knowledge of the parts alone. In systems theory, the whole could be greater than the sum of the parts. The real leverage in most management situations lies in understanding dynamic complexity, not detailed complexity (Senge, 1990). Instead of adopting a rational approach where only one correct explanation exists for how data is connected to theory, a systems approach is adopted where knowledge is built up from the studied indicator effects. This means that the forces influencing the system are important. Further, the relationships are not necessarily deterministic or stochastic. It is also important to see the processes of change for the system, rather than taking snapshots.

Results from a multiple explorative case study on how performance is perceived and measured within large organizations developing complex products and systems within telecommunications, heavy vehicles, and automation are presented in this paper. The focus in this research is primarily on the parts of the case study involving the perception of performance. The explorative multiple case study was performed in accordance with the approach presented in (Yin, 2003). A case study research strategy focuses on understanding the dynamics present within a single setting (Eisenhardt, 1989) and is therefore suited for exploring the perception of performance in complex PD. A total of 49 semi-structured interviews with open questions were held at the five case companies. The questions asked were stated in such a way that the respondents were encouraged to talk about what they thought important. The respondents were managers and decision makers at different levels of responsibility within the organization. Every interview lasted between 50 minutes and 2 hours.

3. The Product Development Organizational Performance Model (PDOPM)

In an attempt to clarify the confusion in terminology used to describe performance, (O'Donnell & Duffy, 2002) developed a performance model within engineering design, based on the IDEF0 framework (Colquhoun et al., 1993). A general model of an activity according to the IDEF0 is shown in Figure 1.

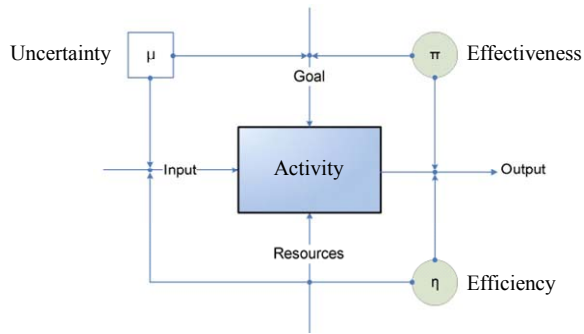


Figure 1. An activity uses resources to transform an input to an output under the direction of goals and constraints. The relation of uncertainty (μ), effectiveness (Π), and efficiency (η) to the input and output variables is also shown. The figure is inspired by (O'Donnell & Duffy, 2002)

An activity uses resources to transform an input to an output under the direction of goals and constraints. The input refers to the initial state of knowledge, while the output is the final state of the performed activity. The resources represent not just the people involved in the activity but also other resources e.g., computer tools, materials, techniques, and information sources. Goals are specific elements of knowledge that direct the change in the state of the activity from the initial input to the final output state. Further, (O'Donnell & Duffy, 2002) use this activity model to define effectiveness and efficiency. Effectiveness is defined as how the output meets the goal, i.e., was the intended output created? Efficiency is defined as the difference between the output and the input, divided by the resources consumed by the activity i.e., the cost of performing the activity. Uncertainty is defined as the difference between the goal and the input i.e., a measure of the new knowledge required by the activity to produce the intended output (Johnsson et al., 2008).

With performance and the definition of PD in mind, we propose to divide the PD process into three generic levels of activities: product strategy, project management, and product activities. These generic activities are then related to each other in the PDOPM through the IDEF0 framework. In the following subsections the PDOPM, is presented (see Figure 2); in (Johnsson et al., 2008) a more detailed presentation of the model is given.

Product strategy in the PDOPM

In business, value creation is typically measured by profitability and long term growth. It is therefore important to establish a continuous process for developing and delivering a steady stream of products, based on its business model, which offers unique and differentiated benefits to a chosen set of customers (Spitzer, 2007). Aligning the product strategy with the business strategy is important for a successful PD process (Ernst, 2002).

In this research, product strategy is viewed as a pattern of decisions and actions performed today to ensure future success. In the product strategy, the decisions of what products to develop and why, to fulfill the business strategy are made. Further, within the product strategy it

is important to balance the internal and the external perspectives e.g., the customer and market perspective with the perspectives of e.g., the internal capabilities and the performance of the current PD projects. If there are changes in the market or difficulties within a PD project, appropriate precautions need to be taken. Once it has been decided what is to be developed, it will serve as a goal for the project management activity to fulfill.

Project management in the PDOPM

The PMBOK (PMBOK, 2004) describes an objective as something toward which work is to be directed, a strategic position to be obtained, or a purpose to be achieved. Once the product strategy activity output is decided, the project management activity is initiated to ensure that the selected customer needs are realized in an efficient and effective way. The Stage Gate model is a tool, commonly used by product managers or similar persons responsible for the business effects of the project, to supervise and secure that the right products are developed (Cooper, 1993). The role of the project management is to make sure that the output from the product strategy is transformed into activities to be performed by the resources involved in the product activities.

Product activities in the PDOPM

The product activity includes all activities needed to fulfill what has been undertaken by project management to the product strategy, in order to design and implement the product. Within a PD project, it is important that the goals from project management are broken down into well-defined activities that can be realized in an efficient and effective way. To be successful in the product activity it is important that all activities are performed in close cooperation with the project management activity. This is especially important for two reasons, first, to ensure that the right product is being developed and second to monitor the progress in order to keep the budget and time plan. If there are deviations it is important to be aware of these early on in order to address them.

Effectiveness and efficiency in the PDOPM

By modeling the product strategy, project management, and product activities as activities in the PDOPM, it is possible to reason about how these activities relate to each other. Moreover, it is possible to explicitly define uncertainty, effectiveness, and efficiency for each activity, resulting in a holistic conceptual model of performance in the PD process. In (Johnsson et al., 2008) a more detailed description of uncertainty, effectiveness, and efficiency for each activity, is given. In this research effectiveness and efficiency are defined for the complete PD process.

PD effectiveness (Π_{PD}) is defined as how the output of the product activities meets the goal of the product strategy. In this case, the goal is to fulfill the business strategy, thus, it is important that the output is in line with

the business strategy. To do so, ownership from upper management is encouraged and it is an important success factor for the PD process (Ernst, 2002). Effectiveness in the PD process is the important foundation of a successful development process. However, there is no easy way to measure and no one factor to manage, in order to improve the PD effectiveness. Instead, PD effectiveness should be viewed as the result of having well functioning product strategy, project management, and product activities that dynamically work together in order to develop successful products. PD effectiveness is the aggregated result of the effectiveness for the three activities in the PDOPM.

PD efficiency (η_{PD}) is defined as the difference between the output of the product activity and the input to the product strategy, divided by the total resources

consumed in the product strategy, project management, and the product activities in order to produce the intended output. Moreover, PD efficiency is important to make sure that the invested resources are used in the best possible way. The PD efficiency can be improved by increasing the output or decreasing the cost for the resources consumed by the activities.

The PD process depends on both efficiency and effectiveness in the performed activities in order to be successful. The iron triangle is often used to evaluate projects, thus focus turns to the resources and the output aspect of the product activities. Hence, the effectiveness and value perspectives of what is being developed are missing or taken for granted.

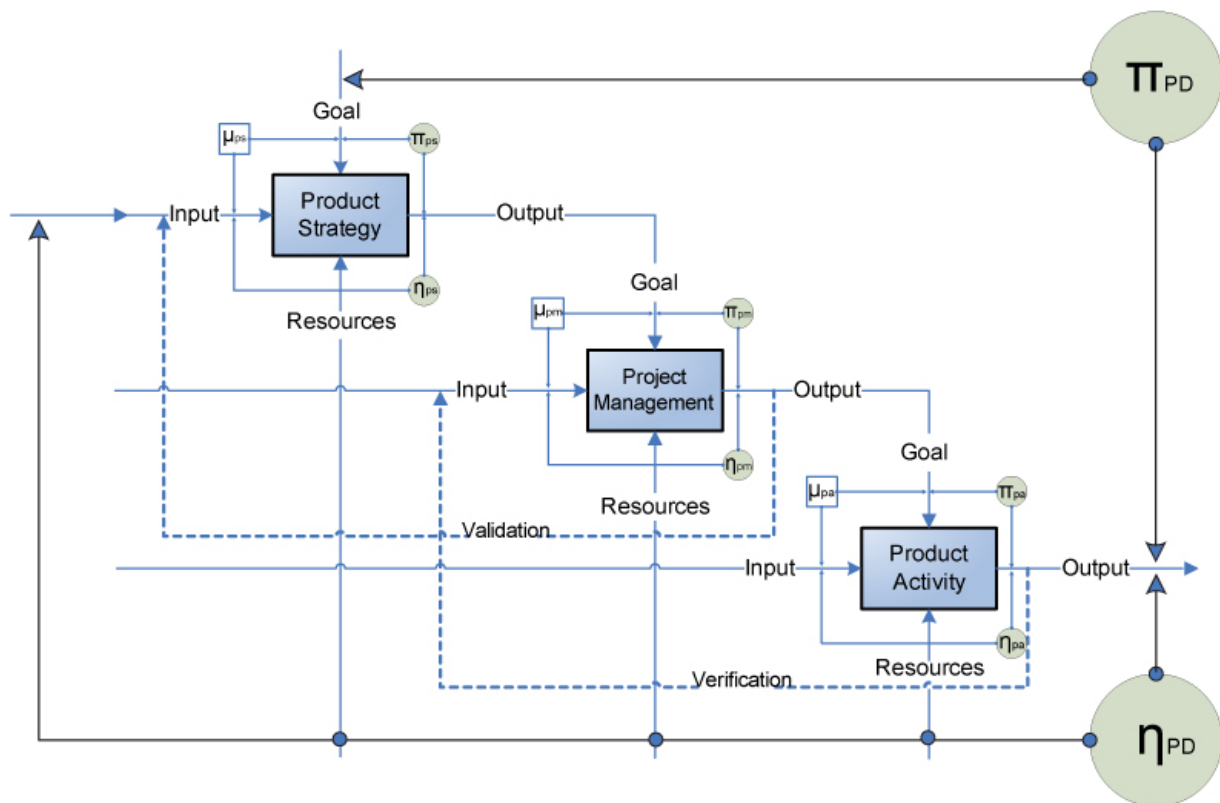


Figure 2. The proposed PDOPM model with the three generic levels of activities: product strategy, project management, and product activity. The relations of uncertainty (μ), effectiveness (Π), and efficiency (η) are also shown in the figure, both for each activity and for the complete PD process.

5. Perception of performance within five companies developing complex products and systems

In this section the findings from the explorative case study are presented through five typical citations of how the respondents perceive performance in the PD process. The selected citations are typical and illustrate how performance in the PD process is perceived from the respondents' own experience and their role within

the organization. The perception of performance differs between respondents and no indications of a company specific view of performance could be identified.

Citation 1

Performance within PD is to do the right things, as quickly as possible, and with as low cost as possible.

This citation mainly relates to the product activity in the PDOPM. Both efficiency and effectiveness are related to this perception of performance. Effectiveness is emphasized through developing the right things. This citation clearly illustrates the common phenomenon of taking for granted what the right things are. Focus often

turns to the product activities, while the product strategy and the project management activities are forgotten.

Citation 2

Performance within PD is to work with process improvements to shorten the lead time and make sure that the whole chain is involved at the right time.

This citation focuses on the efficiency of the processes used in the product activities. The importance of the implementation activities as well as the efficiency part of performance is being emphasised.

Citation 3

Performance within PD is to shorten cycle times, deliver on time, and reduce time to market. If you look at the calculations, the normal cash flow, cash in cash out, for a normal net present value calculation, it is clearly shown that it is important to reach a positive cash flow as quickly as possible. It is equivalent to having a short time to market. Quality is also important, we have high costs for everything that is delivered to a customer and not working properly.

This citation is similarly related to the product activities and the efficiency aspect of performance. The strategic aspect of what to develop and its effect on the cash flow is never mentioned; this perspective is similar to an efficiency perspective on manufacturing.

Citation 4

If it took three years to develop a new product a couple of years ago, I would want it to take 6 months today. The processes and steps that are required to develop a new product shall be more efficient to decrease the lead time. The pace should be higher and higher. You get more development per spent SEK.

This citation clearly implies the favouring of an incremental PD process and the citation is heavily related to the product activities in the PDOPM. Further, the efficiency aspect of performance is the obvious focus, on the expense of effectiveness.

Citation 5

Performance within PD is about managing the four dimensions time, product cost, project cost and quality within a project. Efficiency is about not having to redo things and focus on what creates value and doing things right. Effectiveness is about doing the right things and it is the product manager that decides what to develop. What to develop is seldom purely a R&D decision but more of a market strategy decision. This has a high effect on the performance of product development.

This citation relates to the product strategy, the project management and the product activities in the PDOPM as well as both the efficiency and the effectiveness aspects of performance. This citation is one of few that even mention value creation or adopt a

holistic perspective to performance in the PD process.

Summary and discussion

To summarize, the perception of performance in PD almost exclusively focuses on shortening lead times, decreasing costs, and increasing quality. There seems to be a strong relation to the iron triangle of time, cost, and quality also within the perception of performance. This may be the natural consequence of having the PD organized in projects. From the citations it seems like it is taken for granted that the right product is being developed. Only ten percent of the respondents reflected on the product strategy and its effect on performance in the PD process. This may be the result of having large organizations developing complex products where no person can have a complete holistic view of the process.

One possible reason that time, cost, and quality are mentioned in practically every citation of performance may be that they are relatively easy to quantify and measure. Hence, it may be the case that the perception of performance has been influenced by what is measured. Ideally it would be the other way around i.e., to improve performance, a set of measurements are chosen to get management attention of what is important in order to achieve this objective. If the latter is true, there is a need for a change in the perception of performance within PD. This argument is supported by (Chapman & Ward, 1997) who argue that performance is perceived primarily in terms of dimensions that can be measured. If that is the case, the perception of performance needs to be changed before any other more holistic ways of measuring the performance can be developed.

Validity

The validity of the presented results of the explorative case study is divided into construct validity, internal and conclusion validity, and external validity as well as reliability (Yin, 2003).

Construct validity concerns how the study relates to the research question. In this study the question asked to the respondents also is the one investigated. However, as revealed in the literature, the terminology is ambiguous and this may have affected the respondent's perception of performance. When the respondent's perception of performance in PD was asked for, it was not explicitly revealed what the interviewee's view of the performance and PD. The questions asked were stated in an open way in order for the respondents to interpret from his or hers experience and position within the case company. Further, all interviews were anonymous and it was made sure that it would not be possible to trace who said what.

Internal and conclusion validity aim to ensure that the conclusions drawn are correct. A representative selection of respondents was made by ensuring that the participants have different roles within the

organization. Almost every selected respondent was able to participate in the interview, reducing the risk of mortality. Respondents not being able to participate were replaced by a person with a similar role within the organization. The possibility of “fishing” for answers i.e., asking leading questions during the interview was minimized by the use of open questions. Moreover, the interview ended by asking the respondent if anything important was left out.

External validity is about how the results can be generalized. This is a particular concern for a case study, where it always can be discussed to what extent the observations are particular to a certain environment, or whether they are examples of general phenomena. The conclusions are drawn from a multiple case study with respondents from five different organizations. Still, it can not with certainty be said that this is the case, and to draw such conclusions, further studies are needed. So far only five organizations have been studied in Sweden.

Reliability involves the possibility of others to replicate the study and draw the same results. This study could easily be replicated by other researchers but the same result may not be achieved because an organization changes continuously and through the interviews only a snapshot of the current state was taken. It would be interesting to see the result from a similar study in other countries to see if there are any similarities.

6. Product development efficacy

The major finding from the perception of performance is the neglecting of the product strategy’s effect on PD performance. It seems that it is taken for granted that the right product is being developed. One reason may be in the limitations and ambiguity in the words describing performance. Thus, the term PD efficacy is introduced.

In the Oxford Advanced Learner’s Dictionary (Wehmeier et al., 2005), efficacy is described as the ability of something, especially a drug or a medical treatment, to produce the results that are wanted. Moreover, in (Alegre et al., 2006) product innovation efficacy is described as something reflecting the degree of success of an innovation. Efficacy is often used in the sense of capacity or power to produce a desired effect.

With the definition of PD presented in Section 3 in mind, PD efficacy is introduced to illustrate the capability to first identify or create a market opportunity and second, to fulfil this opportunity by developing a product fulfilling precisely this, by the product strategy identified, market opportunity. A report by Booz Allan Hamilton reveals that most new products, from automobiles to washing machines, are over engineered as a result of not communicating and managing the customer needs properly (Koehler & Weissbarth, 2004). An important aspect in the quest for PD efficacy is the product strategy activity since it is

where the balancing act between what is needed by the market and the capabilities within the organization is decided on. If this is not performed successfully, it can not be corrected within the project management and product activities. By focusing measurements on time, cost, and quality, often in a lagging perspective, what to be developed is never questioned when the PD process is to be evaluated.

PD efficacy is also dependent on the project management and the product activities, once it is decided what to develop in order to avoid over or under engineering when designing and implementing what has been decided in the product strategy. Moreover, PD efficacy is to be viewed as the result attained through continuously managing the uncertainty, effectiveness, and efficiency in each of the three generic levels of activities in the PDOPM. If the customer needs changes during the development of a new product, it has to be reflected in the PD project in order to secure that the right product is developed. High performance in the PD process is achieved when there is efficacy in the complete PD portfolio.

7. Discussion and conclusions

Time, cost, and quality i.e., the iron triangle are common measurements of performance within projects. PD is often performed in a project setting, thus evaluated accordingly. A recent study within the utility industry shows that there is a weak link between the iron triangle and financially successful products. Moreover, the results from the explorative five case studies of how performance in complex PD is perceived clearly show that performance is perceived in terms of time, cost, and quality. The perspectives of value creation and if the right product is being developed were often missing when asking about PD performance. In this research it is therefore argued that a change in the perception of performance is needed, before there can be any changes in the development of new measurements. This may only be achieved by changing the mindset of the people involved in the PD process.

The explorative multiple case studies also showed that there is no common view of how performance is perceived within any of the five organizations. But, since all five case companies are successful, it could be that this information is managed as tacit knowledge. Tacit knowledge is defined in (Foos et al., 2006) as knowledge that cannot be articulated or verbalized; it is a knowledge that resides in an intuitive realm. Since the subject of tacit knowledge transfer, content and process, is poorly understood it may be a substantial risk if performance within PD is treated this way. Thus, it would be difficult to improve the performance in a structured way within large organizations.

To address the need of a more holistic view of performance, it is argued that the PD process, from a performance perspective, should be divided into three generic levels of activities: product strategy, project

management, and product activities. These activities are related using the IDEF0 framework in the PDOPM. Thus, it is possible to reason about uncertainty, effectiveness, and efficiency for each generic activity level. Furthermore, PD efficacy is also introduced in this research to describe the capability of identifying or creating a market opportunity and being able to develop and deliver a product fulfilling exactly what was identified as market opportunity. PD efficacy is needed in order to change the mindset of how performance in PD is perceived within industry, to also include the product strategy activity. By using the PDOPM it is possible for managers and decision makers to conceptually reason about performance in the PD process from a holistic perspective and identify where improvements are needed in order to improve the performance.

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