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MAKING THE IMPORTANT MEASUREBLE

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Performance measurements related to product development typically focuses on what is easy to quantify and not necessarily what is important to measure. This research uses a case study approach to test a new model for designing performance indicators (DPI) based on what is important for a specific organization developing new products. The foundation for an effective performance-measurement system is that the performance measurements are derived from relevant performance criteria and objectives. The proposed DPI method is therefore based on three consecutive steps. The first step is to decide what performance objectives are needed to be fulfilled in order to realize the pursued strategy. This step is followed by the identification of performance criteria / success factors that will contribute to the realization of the performance objectives. Performance criteria are typically related to what needs to be achieved in order to fulfill the objectives while success factors focus more on how they are to be fulfilled. Based on the most important performance criteria /success factors the supporting performance indicators can be derived from the literature or by using the performance measure record sheet. The performance allocation tracker is developed as a result of applying the DPI method in a real case and it is an indicator of the performance of the studied development project. The properties of the indicators resulting from using the DPI method include similar characteristics as leading indicators of performance. It is concluded that by focusing on performance criteria and success factors in the development of performance indicators, leading indicators of performance is derived.

Keywords: Performance, Measurements, Metric, Leading indicators, Complex products, Product development

Introduction

All functions related to product development are under great pressure to continuously deliver sustainable value to stakeholders, by bringing new successful products to the market. Performance measurements are of great importance in this context, since without them we cannot answer the most basic questions such as “how well are we doing”, “what have we learned” and “what should we do in the future” (Tatikonda, 2008). Performance measurements are also powerful and may affect people’s behavior (Hauser and Katz, 1998). Even where performance measurements are introduced purely for purposes of information, they are probably interpreted as definitions of the important aspects of that job or activity,

hence have important implications for the motivation of behavior (Ridgway, 1956). Thus, it is argued in this research that there needs to be a relation between what organizations perceives as important and the performance-measurement system in order to support improvements of the product-development process.
In a recent survey of commonly used performance measurements related to the development of new products in the US (Teresko, 2008), the following five metrics were those most commonly used:

(i) R&D spending as a percentage of sales
(ii) Total patents filed/pending/awarded/rejected
(iii) Total R&D headcount
(iv) Current-year percentage sales due to new products released in past X years
(v) Number of new products released

These five metrics are all important and useful on a high aggregated level in a product-development organization, typically at a top executive level. However, these metrics do not support managers in their everyday work of monitoring and managing the execution of product-development projects. These metrics are either input or outcome oriented measurements, e.g. the current-year percentage sales due to new products released in the past X years is a measure of the result developed for up to X years ago, and says little about the current development activities. In contrast to those high-level measurements are those focusing on ongoing activities in individual projects, often in terms of deviations from the project plan or budget, once the deviation already has occurred.
This is in line with a conclusion derived from our previous research, that performance is often measured in terms of what is easily quantifiable and not necessarily what is important, in order to support the obtaining of the desired performance results (e.g. Cedergren, 2011). Further, measurements of performance are mainly focusing on the later stages of the product development process. Hence, there is a risk that focus is on what is measurable, rather than on the importance of what is measured. The fundamental task here is to avoid McNamara's Fallacy[1]:

We have to find a way of making the important measurable, instead of making the measurable important.

The key challenge, as argued in this chapter, is not to design new performance indicators. In a review of the literature by Adams et al. (2006) it was concluded that there is already a sufficiency of measurements defined in the literature. Instead the challenge lies in understanding the performance criteria and success factors that are important in order to fulfill the objectives set by the organization or a development project, in order to decide on the "right" measurements. This is in line with the arguments by Gharajedaghi (2006) that the

[1] Named after former US Secretary of Defense Robert McNamara.

foundation for an effective performance-measurement system is that the performance measurements are derived from relevant performance criteria and objectives.
This paper describes the work of investigating how important performance aspects, success factors, can be evaluated *during* the development of new products in order to support the interactive nature of the product and project management functions. What is important differs between companies due to various circumstances and preferred ways of working. It is argued that a method is needed to support managers' work in developing a context dependent evaluation system based on their specific management needs of success factors. It is argued in this research, that it is important to focus the performance-measurement system on supporting managers and decision-makers *during* the development activities, in order to increase the likelihood of a successful end result. More specifically the research question guiding this research is:

How can performance measurements be designed in order to support managers and decision makers in deploying proactive activities ***during*** *the development of a new product?*

Unfortunately there are few research studies describing how to design performance measurements according to the contextual needs of the organization. In a review by Neely (1997) the following guidelines for how to define performance measurements where argued for. The performance measurement record sheet should include: Title, Purpose, Relates to, Target, Formula, Frequency, Who measures?, Source of data, Who acts on the data?, What do they do?, Notes and comments. Furthermore, performance measurements must reflect the objectives for and responsibilities of the person(s) or activities that are being measured. However, these guidelines, even though important, describe a mechanistic view on performance-measurements design. They are more requirements for deploying measurements than for designing them.

Research Framework

The foundation for an effective performance-measurement system is that the performance measurements are derived from relevant performance criteria (Gharajedaghi, 2006) and objectives. When performance in product development is defined it is often in terms of efficiency and effectiveness (Neely, Gregory *et al.*, 2005). However, most definitions of efficiency and effectiveness do not support the evaluation of these performance dimensions. In Figure 1 an attempt was made to clarify the confusion in terminology, by extending the IDEF0 model of an activity, used by O'Donnell & Duffy (2002) to define efficiency and effectiveness, to also include the knowledge gap. The knowledge gap is defined in Figure 1 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.

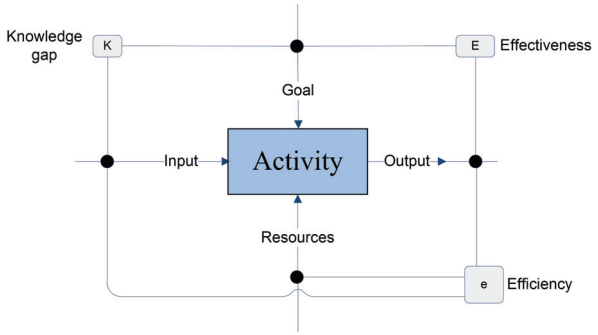

Figure 1. The IDEF0 model of an activity including the definitions of effectiveness (E), efficiency (e), and knowledge gap (K).

In this research, performance in product development is viewed in line with the arguments by Ermolayev and Matzke (2007) who suggest that the term performance is derived from the root concept for intentional action. Hence, performance should be defined as intentional action. This is of central importance as the performance of something is always context dependent. Not all actions are intentional. The notion of intentional action can be contrasted with accidental, as well as with unintentional action. This may be difficult to identify in a performance-measurement system where the focus is often on the output or the outcome of an activity. In this research it is suggested that what is sought of people engaged in product-development activities is goal-directed adaptive behavior, guided by the overall performance objectives set by the organization. This is in line with one of the generally acknowledged findings in the performance-measurement literature that performance measurements should be derived from strategy (e.g. Moxham, 2009).

A Method for Designing Performance Indicators

A method for designing performance indicators (DPI) consisting of three consecutive steps is proposed, as presented in Figure 2. The first step of the DPI method is the performance objective set by the organization that should be reflected in the performance-measurement system. Performance objectives should be interpreted as the objectives to be achieved in order to realize the pursued strategy. Performance criteria and success factors are identified in the second step of the DPI method on the basis of the performance objectives selected. An understanding of what is needed and how it is to be executed is developed by iterating the performance criteria and the success factors. In the third step, the important performance criteria and success factors are then translated into appropriate performance indicators that may be used to evaluate the current state of operation. Performance indicators can be identified from the literature or be defined as what is needed in achieving the important performance criteria and success factors.

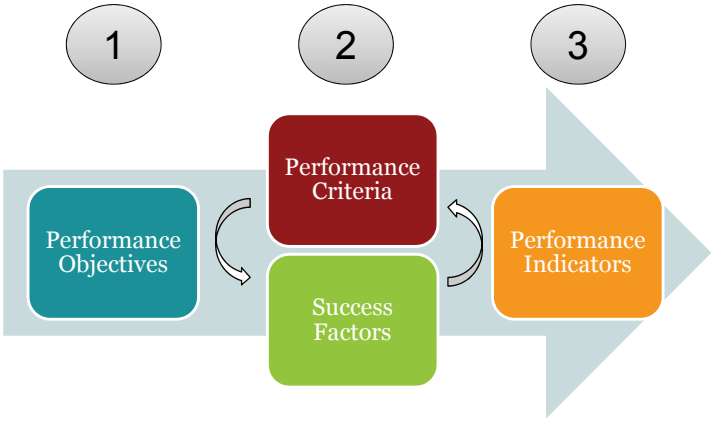

Figure 2. The proposed method for designing performance indicators (DPI).

The GQM paradigm (e.g. Mashiko and Basili, 1997; Basili, Lindvall *et al.*, 2010) is, similar to the proposed DPI method, a three step approach including goals, questions and measurements, developed within the software-engineering literature. One main difference is the inclusion in the second step of the generation of questions to be answered by the measurements in order to achieve the goal. The GQM paradigm has mainly been practiced within the software-engineering literature.

The IDEF0 model of an activity presented in Figure 1 is are central support tool in all of the three steps in the proposed DPI method. The IDEF0 model may be used as a starting point for modeling the organization of product development. The activity model may also be an important starting point when analyzing and breaking down the performance objectives. Analyzing the important major activities from the point of view of knowledge gap, efficiency, and effectiveness is the first steps in identifying relevant performance criteria and success factors. It is argued that developing measurements using the DPI method will result in new measurements that will support managers in improving performance.

Methods and Methodology

A case study approach was used to test the proposed DPI method. The case study, presented in this paper, was conducted at a market-leading company that recently has identified a need within the organization to make the product management function more explicit in order to manage their product portfolio and monitor ongoing development projects more efficiently. The unit of analysis in the case study was the development process related to the development of a new product. A development project was selected and used as a starting point for selecting interviewees. The development project was selected because of its character as a radical development project, mainly because the product is new to both the company and the industry. However, the new product leverages knowledge within the organization from the current product portfolio.

Data collection was mainly conducted through eleven open and semi-structured interviews with ten employees in the case study company, together with company specific

documentation of the development project and process. To obtain a holistic picture of the performance-measurement process interviewees were chosen in a systematic way from different departments and functions with personnel on different levels having dissimilar backgrounds and experiences. Typical roles were line managers, technical experts, marketing managers, product managers and project managers. The interviews were conducted with two researchers present. The questions asked were stated in such a way that the interviewees were encouraged to talk about what they thought important for them to be able to perform their work with a high degree of performance. The interviewees were all experienced managers and decision-makers at different levels of responsibility within the organization. Every interview lasted between 1 and 2 hours. In total 10 hours of interviews were recorded and analyzed. All interviews took place at the case company. The data collection part was concluded by a workshop in order to verify the findings and results.

The collected data was first analyzed by the two researchers individually and then together by listening to the recorded interviews and categorizing the findings according to the predefined categories in the IDEF0 model in Figure 1; Knowledge gap, Effectiveness, Efficiency, Input, Goal, Resource, and Output. During the case study, the researchers had access to the documents related to the project (e.g. project organization, process descriptions, administrative documentation, and product documentation).

Case Company Organization

The case company is a business unit within a Fortune 500 company, being the market-leader in their primary market. There are two main types of development activities within the case company, development of standard products and order specific development projects. In the latter the standard product is tailored to fit the needs of a specific customer. The products developed are complex products, i.e. products built around a platform and/or architecture, reusing components to keep the development costs low, something that is important due to the relative low volumes of these types of products. Further, these products include electronics, mechanical, and software components, making the need for cross-functional development teams important. In order to manage their product portfolio and to monitor the performance in ongoing projects, senior management has identified the need for a new function within their organization – the product manager. The development project studied in the case study was chosen since it is a radical development project and of great importance for the company's future success in securing new orders from customers. Radical development projects are typically more difficult to evaluate using traditional methods in terms of time and cost.

One of the objectives of the interviews was to understand how the product-development activities are organized in practice for a specific development project. All the interviewees were asked to discuss, from their point of view, input, resources, goal, and output on the basis of the development project. The product-development organizational model as shown in Figure 3 is a result of this work.

The model was designed to give a schematic overview of how the different activities are involved in the development of a new product at the case company. The three central activities identified, business development, product management, and development project activities, are identified as the main activity levels in the development organization. Business development, product management, project management, and engineering are presented in the following sections.

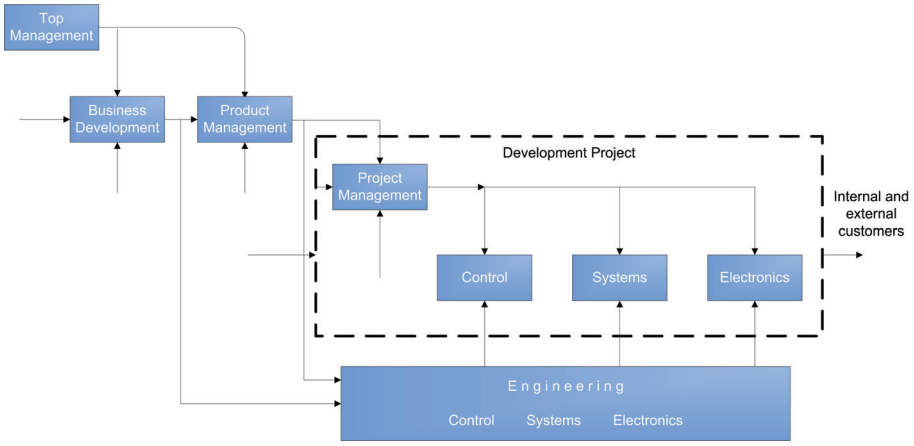

Figure 3. Organization of product development at the case company

Business Development Activity

The main responsibility of the business development activity is to develop a strategic point of view - what are the key future success factors. The business development activity is responsible for one of the product branches of the company with a turnover of several billion SEK. The business development involves many activities related to marketing plans and road maps for the existing product range. About one third of the work involves working with development projects. Typical interface to the business development involves both internal and external customers.

The business development activity role also collaborates closely with tender projects for which an order specific development project is tailored from the standard product to fit the needs of a specific customer. Business development was involved in the decision to begin the development project, by presenting an idea for a specific tender project in which the application could be beneficial. The resulting decision to invest in the development of this new product was, however, a joint decision, several stakeholders being outside the business unit. This ended up in the development project being pulled and not pushed to the market as is often the case when new technology is developed.

Development projects are often financed by a fixed development budget that sets the frames for the development work. The objective is to carry out as much development work as possible on the basis of the available budget. Business development presents a proposal on how to invest the budget in a portfolio of development activities. The most important aspects, regarding the developed products, are quality and functionality, even if it is not always

communicated in the organization officially. One issue is that costs commonly exceed budgets in development projects. There is currently a strong focus on lowering the price of the product to the customer. In the end it is often the price that determines if a customer will buy the product or not, as long as it satisfies the functional and other requirements.
More recently, the case company has identified a need for more radical innovation projects in the development portfolio; there being too much focus on the incremental improvements of already established products. There are no formal performance measurements related to the business development function.

Product Management Activity
One of the primary objectives of the product management activity is to allocate resources in order to finance development projects, on the basis of the available development budget and according to the roadmap for the current product portfolio or development of new products. Hence, the road-maps of the different products are of central importance. Product management is a new function in the organization and during the interviews it was still under development. Previously the associated activities were part of the responsibility of the engineering organization. The product management function has a clear focus and is responsible for the effectiveness of the product development.
A central task for product management in this work is to ensure that the projects receive the resources needed, according to the project plan. However, it is project management that estimates and plans what activities are to be conducted in a development project. This is negotiated with the different resource owners within engineering. The development projects are managed through a company specific gate model that controls the financing of the development through one phase at the time.
The formal management processes focus on efficiency through standardization and reuse of technology. Thus, the formal management system favors incremental rather than more radical product development projects. Product management is further responsible for the requirement specification for the development project on the system level. However, as the project is executed, the functional and other requirements are further detailed and the requirements for the different subsystems become more detailed. Hence, managing the requirement specification on a system level is a key task for product management.
There are no general measurements for how the product management performs in development project. Instead, the product management function is evaluated in relation to objectives for specific projects. The focus of product management, in the development project studied will be the final product cost, the particular functional requirements of the product e.g. weight and reliability. The product management activity works in close collaboration with the project management activity.

Project Management Activity
The project management activity has both a technical and a general project manager role. The technical project manager leads the formal decision-making process regarding the design of the product in the project. One of the primary functions of the technical project management

activity is to act as a system integration manager with the responsibility for the success of the technical system. The general project management role is to plan, monitor, and control project progress with respect to time and cost. The project is synchronized by meetings with one team leader from the larger functional groups i.e. systems, control, and electronics but most communications within the project is performed outside meetings rather than in meetings.

The technical challenges in the development project will be overcome; there are no unrealistic demands on, for example, the product cost. The overall objective in the early phases of the development is to learn as much as possible before the industrialization phase of the development project. The organizations judgment if the development project is successful or not, is purely related to the technical performance of the final product, not if the project has been completed within the budget.

Development projects are typically evaluated through project cost and progress, product cost, and the current state of the development. The earned value methodology, with cost performance index and schedule performance index, is used for monitoring the development projects. The project manager updates the earned value every month. Different reviews of the development project are also prepared throughout the project life cycle to identify deviations from budget. One of the problems is to know if the project will be delay while this can be corrected. This might be the consequence of having too many projects executed in parallel. Since, there are often only a small number of key expert resources that are needed in many projects, both development and order projects, the order projects are often given priority.

The Engineering Organization

It is within the engineering organization that the functional engineering resources are organized, e.g. control, systems, power electronics, mechanics, and lead engineers. Most of the activities related to the engineering organization are within order projects. Currently, there are about fifty order projects in the portfolio executed in parallel, with various engagement levels. Engineering is involved to approximately one third in global product-development projects, initiated by product management, and two thirds is order specific development activities controlled more locally. Hence, development projects that deploy the same resources may be given a lower priority than order projects since the date for delivery of the product to the customer is well-defined. About 500 people are engaged within engineering in very different development activities from software development, and electronics development, to mechanical design.

Product-development activities are necessary to qualify for tender projects, thus selling the company's products to the customer. Hence most of the development is market pulled and not technology pushed. Typical measurements within the engineering organization are earned value, and re-use within the product portfolio. Earned value is regarded as a good ways to evaluate the progress of the development project according to the project plan.

Applying the DPI Method in Practise

In this section, the use of the proposed DPI method, as presented in Figure 2, is demonstrated. The three steps according to the proposed methodology have been followed and are presented accordingly in the following subsections. The first step clarifies and decides on the performance objectives. This step is followed by iteratively deriving relevant performance criteria and success factors; this is the foundation and important step for developing the relevant performance measurements in the third step that will be adopted by the organization. These three steps will be further presented in the following subsections.

Step 1: Performance Objectives

It is important that the performance objectives are compatible with the strategy of the organization. Recently the case company has identified the need to bring more radical products to the market. However, the formal measurement systems currently focus on monitoring product standardization and reuse. The earned value methodology, also used within the case company, monitors resource consumption in a lagging perspective, i.e. resources already consumed.

It was decided with the case company that the required performance objective is to develop measurements that can give early warnings of development projects deviating from the plan. This may enable proactive actions in the ongoing development project and thereby avoid large overruns, something that the current measurement system is missing.

Step 2: Iterations of Performance Criteria and Success Factors

The second step in the proposed approach to developing performance measurements is to break down the performance objective into performance criteria in order to design performance criteria derived from the performance objectives. In this study, focus was on the identification of performance criteria and success factors in the interview study. Performance criteria and success factors in this study are intended to enable proactive actions, in contrast to the reactive actions resulting from lagging measurements. Performance criteria relate more towards what needs to be done, while success factors tend to focus on how it is to be done. By analyzing the interviews the following list of performance criteria / success factors were identified:

(i) A clear target of what is to be developed (Goal)
(ii) Planned resources available, especially key roles (Input and Resources)
(iii) Strong project management (Resources)
(iv) Requirements stability (Goal)
(v) Pre-studies (Knowledge Gap)
(vi) Sub projects, not one big project (Knowledge Gap)
(vii) Team composition (Input and Resources)

The relation to the IDEF0 model of an activity property (see Figure 1) has been added after each factor in order to analyze the affect each performance criteria / success factor has on the development output.
The biggest challenges to the project management activity can be divided into short-term and long-term challenges. In a short-term perspective the challenge is to get resources to the project, and in a longer-term perspective to be ready in time and deliver what has been promised. The development project in this case study was initiated in parallel with a tender project in which the new technology will be adopted. The tender project has affected the development plan in calendar time by demanding the performance of more development activities in parallel, to be able to complete the project in time. At the time of the interviews the development project was staffed with only 60 per cent of the resources planned and it had been like that since the start of the project. The resources needed are preoccupied in order-development projects with a higher priority. This is considered by the project manager to be a risk in the project. However, it is not project management but product management that is responsible for making sure that the resources needed are available according to plan.
On the basis of the list of identified performance criteria / success factors, it was decided in consultation with the case company to focus on what was regarded as the two most important areas i.e. resource allocation and scope. Hence, for the next step in deriving performance indicators, focus was on factor (i), (ii) and to some degree also on (iv).

Step 3: Deriving Performance Indicators
In order to derive relevant performance indicators for the selected performance criteria / success factors the guidelines provided by Neely (1997) were adopted. The result is presented in the following sections.

A Clear target of What is to be Developed
It is possible to monitor the technical scope of what is to be developed by analyzing the requirement specification. It is commonly argued in the project management literature that it is important to have a well-defined set of requirements, representing the objectives, before the project is initiated. In practice, especially for development projects, there tend to be changes in the requirements. In development projects, there could be internal or external changes to the product requirement specification.
There are several possible sources of internal specification changes, but one major cause is the breaking down of the requirement specification into requirements for the various sub-systems after a baseline has been decided on. This is correlated with a risk of identifying further difficulties that may affect e.g. the planned resource consumption or even the possibility of delivering the specified product. The project can visualize the project progress by monitoring the breakdown of the requirement specification. The internal stability may also affect the stability of the requirement specification as a whole.
There could also be external changes to the requirement specification and this is also important to monitor. Possible sources are product management, tender projects, the business development or other sources internal as well as external. These could also be monitored by the number of application areas in which the product is intended to be used. There is usually

a specific tender project or similar in which the product will be used, however as time passes more and more application areas tend to be identified which potentially affects the requirement specification and the development of the product.

One benefit, for managers and decision makers, of monitoring the stability of the requirement specification is that it gives an overview of the sources of changes and an understanding of the stability of the requirement specification. If there are major changes there is also a large amount of uncertainty in the project planning. Hence, there is a possibility that there will be major future changes in the project scope. It is important to acknowledge that there is no optimal value for this measurement; instead the benefit is achieved when the sources are evaluated and changes to the process decided upon are performed accordingly. This measurement can also be used to explain to and give managers a common view of the status of the development project. Further, the requirement changes can be classified according to value adding, non-value adding but necessary, and waste. The frequency of this kind of measurement depends on the current phase of the project and the frequency could be changed accordingly.

Resource Allocation

Resource allocation is of central importance for the case company and can be viewed as a leading indicator for the already established earned value methodology. As is common in many organizations, the portfolio of projects is extensive and includes parallel projects. Hence, there are many development projects competing for the same limited resources. The problem relates more to available competence than the available finance. In the development project studied, senior experts are typically needed in the development work. Moreover, it is important to take a system perspective and see the resource allocation as a whole. Cross-functional development teams are used in the development project and these teams are dependent on their different roles and competences being involved at the right time. There is otherwise a risk of other resources not being able to perform their tasks and there is a risk of a chain reaction if not all resources are available as planned.

It is proposed that one way of measuring this can be the percentage available resources as planned for within a window of the next two weeks. This could also be detailed further by specifying the type of resources needed from engineering e.g. control, system, and converter. This can also be further developed to especially monitor the key resources needed to be able to deliver according to plan. The proposed measurement, the Resource Allocation Tracker, is expressed in the performance measurement record sheet is presented in Table 1.

Table 1. Resource Allocation Tracker

Details: Resource Allocation Tracker	
Title:	Resource allocation tracker
Purpose:	Monitor the allocated resources compared to the plan
Relates to:	The earned value methodology
Target:	100 per cent
Formula:	Percentage of allocated recourses compared to plan in the coming two weeks window.
Frequency:	Every week
Who measures?	Project manager
Source of data:	Project members and team leaders
Who acts on the data?	Project manager
What do they do?	Alert engineering and product management and ask for action.

Discussion and Conclusions

This research aims at increasing our understanding of how to design performance indicators in a product-development context to support product and project managers, in particular, during the development of a new product. The product-development management literature contains few methods or frameworks, other than the GQM paradigm (Mashiko and Basili, 1997; Basili, Lindvall *et al.*, 2010), on how to assist managers in developing relevant performance measurements based on the needs of the organization. However, there are many reports describing theoretical performance measurements. A typical example includes the need for the performance-measurement system to support the pursued strategy of the organization. But few tools for supporting the development of such performance measurements exist. This might explain why performance measurements do not reflect the changes made in strategy, as identified in a recent study by Johnston and Pongatichat (2008).
This research proposes and outlines a method for designing performance indicators (DPI) that supports managers and decision makers in deploying proactive activities *during* the development of a new product. The proposed methodology is grounded on three consecutive steps. The first step is to decide what performance objectives are needed to be fulfilled in order to realize the pursued strategy. This step is followed by the identification of performance criteria / success factors that will contribute to the realization of the performance objectives. Performance criteria are typically related to what needs to be achieved in order to fulfill the objectives while success factors focus more on how they are to be fulfilled. Based on the most important performance criteria /success factors the supporting performance indicators can be derived from the literature or by using the performance measure record sheet by Neely et al. (1997).

A first verification of the DPI method is presented by applying the method in practice using a case study. More specifically the case study described in this research has investigated how to develop indicators that integrate the product management and the project management roles in a development project. Despite, it being the first attempt to apply the proposed method in practice; we believe there are some valuable implications for managers and decision makers, especially for project and product managers in large organizations. The result of the DPI method is performance indicators derived from the performance criteria / success factors of having a clear target of what is to be developed and of the project having the planned resources, especially key roles, available. A clear target can be evaluated by monitoring the changes in the requirement specification, both regarding internal and external to the project, after the first baseline. The second indicator focus on the amount of resources available compared with the committed project plan. Both indicators can be further detailed according to the needs of the organization. As has been demonstrated the indicators resulting from the method are in line with the aim of the method, since both measurements will give managers early warnings of deviations from the plan. The first use of the DPI method resulted in the case company adopting the resource allocation tracker, as a leading indicator to capture the early warnings of deviation from the development plan.

The proposed DPI method can be applied by managers in order to support the development of their own organization-specific indicators, which complement the traditional indicators which focus on time and cost. Additionally, the proposed method illustrates that the design of new performance indicators need not be a tedious process. The focus should instead be on establishing the performance objectives and deriving relevant performance criteria and success factors that can be used in identifying suitable performance indicators.

One conclusion from using the proposed method is that the identification of performance criteria and success factors is the key to success in developing performance indicators. This is the causal link between the objectives and how the organization should evaluate its performance in order to achieve its objectives. It is interesting to see that the proposed performance indicators are relatively simple if they are analyzed by an outsider. The real leverage in the proposed indicators is that they are grounded in the specific needs of the organization as identified in this research and confirmed through workshops at the case company.

This research stress that there is a need for developing measurements that can support managers and decision-makers during the development. Hence, it is leading indicators of performanc that is aimed for. Parmenter (2010) defines seven characteristics of leading indicators of performance:

(i) They are nonfinancial i.e. not expressed in monetary terms.
(ii) They are measured frequently
(iii) They are acted on by the CEO and senior management team
(iv) They clearly indicate what action is required by staff
(v) They are measures that tie responsibility down to a team
(vi) They have a significant impact e.g. affect one or more of the critical success factors.
(vii) They encourage appropriate action e.g. have been tested to ensure they have a positive impact on performance, whereas poorly thought-through measures can lead to dysfunctional behavior.

Comparing these characteristics with the results of the application of the DPI described above acknowledge the fact that all except (iii) also are characteristics of the resulting indicators. Hence there are similarities between leading indicators of performance and the indicators derived using the DPI method. It is concluded that leading indicators of performance may be designed using success factors and performance criteria e.g. by using the proposed DPI method.

Future research

This is only the first verification of the DPI method for developing relevant performance indicators from the viewpoint of the managers and decision makers involved in the product-development organization. There are several future research opportunities related to the proposed methodology. More studies in which the DPI method is tested are needed, in order to ensure replicability of the method. It is also important to follow up on the case study conducted in order to evaluate the result of the proposed measurements after they have been implemented in the case company.

In this paper focus has been on the perspective of objectives and performance measurements. Tatikonda (2008) also argues that two other perspectives are important when analyzing measurements: its metric and the incentives connected to the measurements system. More research is needed to see how the proposed performance indicators, requirement stability and available resources, are affected by other aspects of performance measurements, i.e. different metrics for calculating the actual value and how incentives should be designed in order to optimize the benefit for the organization.

References

Adams, R., J. Bessant, et al. (2006). "Innovation management measurement: A review." *International Journal of Management Reviews* 8(1): 21-47.

Basili, V. R., M. Lindvall, et al. (2010). "Linking Software Development and Business Strategy Through Measurement." *Computer* 43(4): 57-65.

Cedergren, S. (2011). Performance in Product Development - The Case of Complex Products. Innovation, Design, and Engineering. Västerås, Mälardalen University. Ph.D.

Ermolayev, V. and W.-E. Matzke (2007). Towards Industrial Strength Business Performance Management Holonic and Multi-Agent Systems for Manufacturing. Berlin / Heidelberg, Springer 4659/2007**:** 387-400.

Gharajedaghi, J. (2006). *Systems Thinking: Managing Chaos and Complexity - A Platform for Designing Business Architecture*. San Diego, Elsevier Inc.

Hauser, J. and G. Katz (1998). "Metrics: you are what you measure!" *European Management Journal* 16(5): 517-528.

Johnston, R. and P. Pongatichat (2008). "Managing the tension between performance measurement and strategy: coping strategies." *International Journal of Operations & Production Management* 28(10): 941-967.

Mashiko, Y. and V. R. Basili (1997). "Using the GQM paradigm to investigate influential factors for software process improvement." *The Journal of Systems and Software* 36(1): 17.

Moxham, C. (2009). "Performance measurement: Examining the applicability of the existing body of knowledge to nonprofit organisations." *International Journal of Operations & Production Management* 29(7): 740-763.

Neely, A., M. Gregory, et al. (2005). "Performance measurement system design: A literature review and research agenda." *International Journal of Operations & Production Management* 25(12): 1228-1263.

Neely, A., H. Richards, et al. (1997). "Designing performance measures: a structured approach." *International Journal of Operations & Production Management* 17(11): 1131-1131.

O'Donnell, F. J. and A. H. B. Duffy (2002). "Modelling design development performance." *International Journal of Operations & Production Management* 22(11): 1198-1221.

Parmenter, D. (2010). *Key Performance Indicators - Developing, Implementing, and Using Winning KPIs*. Hoboken, New Jersey, USA, John Wiley and Sons Inc.

Ridgway, V. F. (1956). "Dysfunctional Consequences of Performance Measurements." *Administrative Science Quarterly* 1(2): 240-247.

Tatikonda, M. V. (2008). Product development performance measurement. Handbook of New Product Development Management. C. H. Loch and S. Kavadias. Oxford, Butterworth-Heinemann.

Teresko, J. (2008). "Metrics Matter." Leaders in manufactoring Retrieved 2008-09-11, 2008, from http://www.industryweek.com/ReadArticle.aspx?ArticleID=16116.