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PERFORMANCE EVALUATION OF COMPLEX PRODUCT DEVELOPMENT

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ABSTRACT
In this paper a conceptual performance evaluation framework is proposed and discussed. The aim of the framework is to present a tool to stakeholders, involved in dynamic complex product development activities, that assists in developing a mutual understanding of performance relevancy. It is argued that a system perspective and the possibility to tailor performance criteria and measures according to contextual circumstances are needed for performance evaluation to improve work in product development. Companies need to consider what metrics that are relevant or applicable to measure or evaluate the product development process in their own business and context. From a performance evaluation perspective, a categorization of activities in product development is made into: Planning, Implementation, and Sales and Delivery. It is argued that the three activity categories have different objectives and need to be evaluated and managed accordingly if the overall development process is to be considered successful. Moreover, each activity category can be modeled using a generic activity model to derive relevant performance criteria, needed for identifying relevant performance indicators. It is argued that this will have implications on how performance, that is, efficiency and effectiveness, in product development is evaluated at a managerial and designer level, since the performance evaluation framework is based on the performed activities. Three different perspectives – integrated, information and learning – are used as basis for the discussion in this paper in order to accomplish an enhanced understanding of the value of the performance evaluation.

Keywords: complex product development, performance, measurement, system, activity model

1 INTRODUCTION
Industry experiences increasing demand for higher performance in every business process in order to stay competitive in a challenging global environment. The development of technology and knowledge intensive products, i.e. complex products, is challenged by an increased pace of innovation, shortened product life cycles, rapid advances in information technology and globalization. Companies of today need to be able to produce not only one successful product but a steady stream of new products [1]. In this turbulent business reality, performance measurement in product development are gaining increased importance [2]. The level of performance can determine not only a firms overall success and competitive advantage, but also its very survival [3].
It is important to evaluate and assess performance; this information can be used to decide on improvement actions in the product development process. Effective process improvements remain conditional upon both the ability to measure the potential performance gains which may result from an improvement initiative, and the ability to identify potential areas for improvement [4]. With a few identified exceptions (see e.g. [3, 5]), little focus is made on why measurements are so important. There is a risk that the 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."* It is argued in this paper that the main task with evaluating performance should be to support decisions and indicate the benefit with improvement actions, but also to stimulate overall improvement and creativity. Therefore, effective performance indicators need to be designed and maintained, and kept in line with the business and development strategy. If this is not the case measurements can be just as likely to hinder successful innovation in organizations.

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

This paper presents a suggested framework to evaluate performance in complex product development to address the gap in today's product development research, where there are no broadly accepted evaluation models adapted for the needs perceived by practitioners in product development settings. It aims to support managers, decision makers and designers engaged in complex product development with a mindset of performance relevancy. One important aspect with presented evaluation framework is the explicit integration of the goal or objective with the product development activities in the framework. The proposed holistic framework for evaluating performance in complex product development is intended to support the development of measures that are company tailored and based on existing contextual needs.

1.1 Dimensions on Performance in Product Development

Performance is a multidimensional topic, thus making performance evaluation a difficult task. It is therefore not surprising that there are no broadly accepted performance measurements in product development as there are for other business processes, for example in manufacturing [6], even though a huge number and variety of metrics can be found in the literature. To formulate a comprehensive set of metrics that would be applicable to product development in general is unrealistic – if not impossible [7]. Chiesa et al. [8] have identified three reasons why no common, broadly accepted performance evaluation exists: firstly, the degree of uncertainty of an activity is very high; secondly, once completed, the product development output itself is often highly fuzzy and not definable and, thus not measurable; and thirdly, the ultimate result of an activity can usually only be seen after several years, once the developed product has been brought to the market.

What is performance? One important task for managers would be to establish a common inner picture, within the project team or the organization, that helps to clarify performance in complex settings where diverse functional perspectives, stakeholders and interests are represented. It is acknowledged that this is difficult to achieve, and in fact is an issue not only in industry. O´Donnell and Duffy [9] argue that research on performance in product development has been hindered by a lack of clarity, namely a missing definition of key elements. This is in line with Marchand and Raymond [10], who argue that research is more problematic when the basic underlying concepts and definitions in a research area lack clarity, precision, and uniformity. Hence, quotes like "increased performance" or "positive influence on performance" are highly ambiguous, but still commonly seen.

Two commonly used dimensions of performance are efficiency and effectiveness. Neely et al. [11] argue that effectiveness refers to the extent to which customer requirements are being met, whilst efficiency is a measure of how economically the firm's resources are being used to provide a given level of customer satisfaction. Sink and Tuttle [12] describe effectiveness as doing the right things at the right time with the right quality. Efficiency is similarly described as doing things right, and is often expressed as a ratio between expected and actual resource consumption. However, this definition of efficiency seems to be more an aspect of the planning activities and the predictability of the organization than of the product development process itself. In this paper, efficiency and effectiveness are defined according to O'Donnell and Duffy [13], who take a concrete approach by modeling an activity according to the IDEF0 framework [14]. The IDEF0 framework, often used within system engineering (see for example [15]), models an activity as something that uses resources to transform input to output under the direction of a goal. The input represents the initial knowledge before the activity; resources are consumed by the activity in creating the output; the goal is the intended objective with the activity; and the output is the result of the performed activity. Based on this activity model, O'Donnell and Duffy [13] define efficiency as a ratio of the difference between the output and the input (what has been created by the activity) and the resources consumed by the activity. Effectiveness is defined as how the output of the activity meets the goal of the activity (is the intended output created?). This way of modeling the efficiency and the effectiveness makes the different dimensions of performance far more explicit.

1.2 Limitations with Existing Performance Measurement Frameworks

The issue of evaluating what is measurable and not what is important to measure is clearly seen in most performance measurement frameworks. For example, one of the most cited performance measurement frameworks in product development is proposed by Griffin and Page [16]. Their framework focus on four major categories: financial success, customer acceptance, product and project

success, and firm level measures – i.e. measurements of the output of the development project and the outcome of the product development process. The framework introduced by Loch et al. [17] focuses on development process performance in the electronics industry that affects the development output performance, which in turn will influence business success. Despite the criticism that this framework has received (for example O'Donnell and Duffy [18], who argue that there were no process variables with significant relationship to the output measurements of "new product productivity" and "design quality"), this framework is still important since it is one of the few studies with an explicit complex product development context. The framework developed by Griffin and Page [16] is a typical example of a marketing perspective on performance evaluation, and does not support the evaluation of current performance in the product development process. The model of Loch et al. [17] is useful in that it acknowledges the importance of process management leading to development output eventually leading to business success. However the development process is not related to the manufacturing and sales and marketing performance. Davila et al. [19] takes this one step further by explicitly emphasizing inputs, process, output and outcome in their business model of innovation: input is the resources devoted to the innovation effort, and such measurements are to be viewed as leading indicators; process combines the inputs and transforms them into outputs; measurements of the process are real-time measures and track the progress towards the creation of outputs; outputs are the result of the product development effort, and describe what the innovation effort has delivered; outcome measures should capture how the product development effort is translated into value for the company and the net amount of value contribution. It is particularly important to acknowledge what the leading and real-time indicators are – to measure the input and process, and relate these measurements to the output and outcome measurements. How the output and outcome measurements correlate to the invested and existing input is a complex task.

The importance of goal fulfillment is not considered explicitly in existing performance frameworks. An enterprise can be both effective and efficient without being successful, if the targeted objectives are not enabling success. The activity model [14], composed by input, output, goal and resources, is one way to make the objective of an activity explicit. Hubka and Eder [20] have applied the activity model in a design process context. It has been further developed by O´Donnell and Duffy [18], who added a performance metric based on a knowledge perspective, and by Johnsson et al. [21], who applied a strategic dimension. The activity model is also applied in proposed performance evaluation framework as one way to model the developed framework. The intention is that the use of activity models will provide a more nuanced understanding of the nature of the identified improvement and enable to identify ways to obtain high performance in cases where this is needed.

2 FRAMEWORK FOR PERFORMANCE EVALUATION

"*What gets measured gets done*" [22] and "*You are what you measure*" [23] are two well known statements related to the use of performance measurements. Metrics tend to control our view of what is important to measure and what is not, since it is common to concentrate on what it's possible to measure, not on what could be important to measure. In this paper, it is argued that measuring specific product development tasks does not give support for the actual execution of product development. The goal should be to evaluate *how well* the activity is performed, not that the activity *is* performed. Effective evaluation systems needs to iteratively deal with both performance criteria and performance measures [24]. An example of this is that financial measurements are important, but it is also generally agreed that they are most useful at higher levels of management, where they can reflect the success of pursued strategies [25]. Furthermore, the financial outcome in terms of revenues related to product development investment is not usually apparent until several years after the investment decision has been made. Hence, a conceptual holistic framework is especially important within product development, where performance is an elusive concept.

The framework suggested in the following section is based on previous work by O´Donnell and Duffy [18], but integrates different perspectives on product development to support a system perspective on performance evaluation. Furthermore, the framework is conceptual and presented to challenge existing mindsets about the evaluation of performance. A theoretical and generic approach is intended that can be applied and customized to address specific needs and reflect the complexity present in an organization.

2.1 Activity categories

When it comes to performance measurements in product development, the value perspective is most often missing. Instead, focus tends to be on relating performance to decreasing cost and time whilst obtaining sufficient quality [26]. These aspects are important but do not reveal why product development exists in an organization, which ultimately should be to create value for its stakeholders. Reber and Duffy [27] argue that current design approaches do not focus on value in an explicit manner. They present "Value Centered Design", building on the assumption that you are not in business to design products – you are in business to make use of product design to generate value. Value-adding activities can also be to increase competence or creativity. From a value perspective, it is argued that activities enabling value creation are mainly carried out before the scope of the implementation project is fixed and the project is set to be initiated; by focusing on the product development project only, the important aspects of optimizing the possible value may be overlooked.
From a performance evaluation perspective, this paper suggests that all activities of the product development process may be divided into three different categories, which all need to be managed if the overall product development process is to be considered successful [26]. These categories, shown in Figure 1, are: Planning activities; Implementation activities; and Sales and Delivery activities of the product to the customer**.**

Figure 1. Three different categories of product development activities.

Each category requires specific competence and objectives to be prosperous, but at the same time different performance criteria's and thus performance measures for performance evaluation are needed in each category. For example, the output of a planning activity differs from the output of an implementation activity, and so forth. The task of evaluating a market environment analysis activity is different to evaluating design activities. At the same time it is important to acknowledge the importance and how they contribute to the overall performance of the product development process. The three different categories of activities are each possible to model in an activity model.

2.2 Performance activity modeling

It is commonly argued that the performance measurements should be aligned with the objectives of an enterprise – in this case, what is important in order to have a successful product development? In this paper it is argued that a bottom-up approach is common, since focus tends to be on what can be measured and then performance measures are designed accordingly. In the research presented here, the focus is on a more top-down approach. A conceptual framework that supports reasoning about performance both at the overall development process level and at the individual activity level has been developed, in order to establish clear performance criteria. This general framework needs to be dynamic and independent of the prescriptive processes used for the development process. In order to ensure that performance objectives are being fulfilled, one must first have a clear perspective of what performance is (e.g. in terms of efficiency and effectiveness). Moreover, it is important for such a framework is to incorporate a systems perspective in order to have a holistic view of performance evaluation. Hence a common mind set of performance and performance evaluation can be derived – something that is especially important in large organizations, but also useful when the performance concept is ambiguous and several interpretations can be made. The system that develops complex products is often as complex as the products themselves.

From a value perspective the planning activities can be viewed as enabling value; implementation activities may then be interpreted as creating the value enabled by the planning activities; and sales and delivery activities are where the value is capitalized on in monetary terms. The sales and delivery activities category, is often not stressed in the product development literature. However, it is very important in a complex product development context in order to capitalize on the investments. Sales activities of new complex industrial products may suffer if the people involved in these activities cannot communicate the potential benefits of the new products. It is therefore important that the sales and delivery function is integrated in the product development activities. This is especially evident when new technology or functionality is implemented in a product that is new to both the company and/or the targeted customers. The presented performance evaluation framework tries to incorporate the sales and delivery aspects to product development, since this is argued to be important for performance in the sense of turning an output into a successful outcome.
Modeling of performance activities makes up one part of the proposed performance evaluation framework. What differs this approach with the frameworks presented by e.g. Davila et al. [19] and Loch et al. [17] is the explicit integration of the objectives in the performance activity model. In this paper two generic types of objective are considered; the ones generated internally in the product development process as the result of the planning activities and external objectives, generated by the business model, functioning as objective for the planning activity category. On an abstract level the planning activities result in an output that constitutes the goal or objective for the implementation activities, since it is during these activities that the actual designing takes place (as illustrated in Figure 2). The output of the planning activities similarly constitutes the objectives for the sales and delivery activities, which is important because the product development process cannot be considered successful until the new products have been delivered to the customer. Moreover, the output from the implementation activities will constitute the input for the sales and delivery activities.

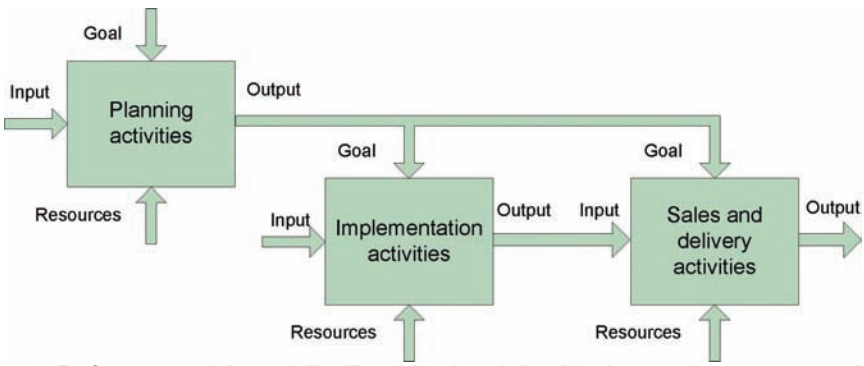

Figure 2. Performance activity modeling illustrating the relationships between input, output, goal and resources to the three activity categories.

The relationship between input and goals is made more explicit through the use of the activity model, where it becomes apparent that the level of maturity for each input determines whether or not it is possible to realize the intended goals. It is argued that this will encourage reflections on how to perform the activities with as limited recourses as possible. This will have a positive effect on the efficiency aspect of performance, but it is also important to acknowledge that efficiency can be raised by increasing the contribution of the activity i.e. output minus input, if this is performed without consuming more resources. If the activity contains tasks that are not value-adding, this is indicated by an increased use of resources. High efficiency is the result of balancing these two aspects with the abilities of the enterprise. The activity model coupled to the identified types of product development activities should be regarded as a tool to communicate what input is needed to achieve the desired output. The framework highlights the benefit of questioning for what purpose the input is needed, instead of using whatever input is available.

2.3 Developing a performance evaluation system

The research behind this paper has developed a conceptual performance evaluation framework to provide guidance to large organizations developing products or systems that are both knowledge intensive and dependent on several technologies. In this paper it is argued that it is important to debate performance evaluation issues in order to get a broader perspective on performance in product development. The evaluation framework aims at introducing a different way of thinking about performance evaluation in product development that can be used as guidance on how to improve performance.

The proposed performance evaluation framework should be regarded as a toolkit that provides stakeholders, that perform different product development related activities (e.g. managers, decision makers and designers), with an overall structure on how to approach performance evaluation. This implies that the framework is project and process independent. Thus even if a product development process is changed in a company, the use of the overall performance evaluation framework is still applicable and relevant, since it is not adapted to a specific design or configuration. A key characteristic of the presented performance evaluation framework is that it requires the user to address performance from a system perspective. Performance activity modeling from a holistic perspective contributes to a more company homogenous understanding of how product development should be performed. There is little value in precise measurements if wrong processes are in use. By considering the dynamic interaction between activities and how these interrelate, the framework can be used to evaluate whether the most accurate process is in use or not from a performance point of view.

The task of implementing a performance evaluation system is complex and iterative due to constant changes in the business environment. Based on the outcome of the performance activity modeling, the next crucial step is to derive overall performance criteria for the development process, using the generic categorization (i.e. planning, implementation, and sales and delivery). By acknowledging the different objectives for the different categories, performance criteria can be established on an abstract level for each activity category. It is important that the performance criteria are relevant and involve both the effectiveness and efficiency aspects of the category targeted, as well as a holistic overview of the development activities. Once the performance criteria have been established the activity model can be used to select suitable performance measures. This can be done by describing the inputs and outputs in the activity model for the targeted activity. It is important to note that if a quantitative value is difficult to attain, it is often better to use a more qualitative evaluation method instead, as long as an objective for the activity can be set and evaluated against. The role of the performance evaluation framework is to help identify where improvements need to be made, rather than on having an accurate quantitative value. This implies the performance evaluation system to be internal and improvement oriented, in contrast to traditional measurement systems, which are more externally focused on reporting green figures (often as a result of focusing on what is easily quantified). The framework provides involved users with a platform for discussions on performance measurements to better understand the flow of activities and evaluate how activities contribute to performance. It is argued in this paper that a performance evaluation system, targeting relevant activities, can be achieved by iteratively following the steps in Figure 3. Changes, forced as well as wanted, are managed through an update of relevant and affected steps throughout the performance evaluation. For example, the change could either require revised performance criteria (and thus a change in performance measures), or might only affect the need to update a particular performance measure.

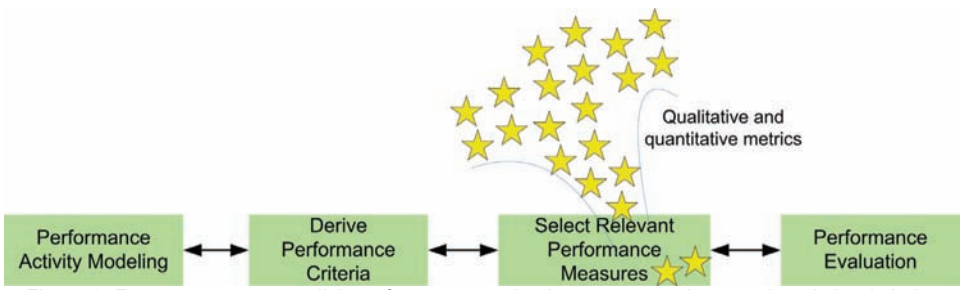

Figure 3. Four steps to accomplish performance evaluation to support the actual work that is being performed in product development.

When applied in different project contexts, the initial understanding derived from the performance activity modeling can be broken down into different subjects for efficiency and effectiveness. Once these are identified, different performance criteria can be derived from the overall "efficiency area". Thus, by approaching development from a system lifecycle perspective (from idea to retirement) it is argued that performance measures can be identified that are relevant for the intended company. Individual metrics could be established to specific parts of the organization, but are extracted from the overall performance identification from a system perspective.

3 A SYSTEM PERSPECTIVE

A system perspective promotes an efficient "flow of activities", and prevents focus on individual product development phases and specific activities. In order to support improved performance it is necessary to cut across the activity categories and achieve an overall system perspective of the evaluation. It is suggested that every activity of any product development process may be categorized in one of the suggested categories planning, implementation and sales & delivery (as illustrated in *Figure 4*). Furthermore, product development activities are performed in a continuously changing environment. In order to verify that necessary adaptations due to new conditions are made in the process, performance evaluation needs to be carried out regularly. The activity categorization of product development easily gives the faulty impression of a linear process i.e. first the planning activities are conducted, and then the implementation activities, followed by the sales and delivery activities are performed. Instead, the performance evaluation framework should be regarded as a categorization of activities that enables continuous evaluation of the activities accordingly. In Figure 4 two different abstraction levels are illustrated: the overall development process level, where the diverse activity categories and evaluation are sequential and possible to map according to specific phases in two exemplifying generic processes; and the specific activity level, where the diverse activities (and thus evaluation) are interchanging and iterative across the three activity categories.

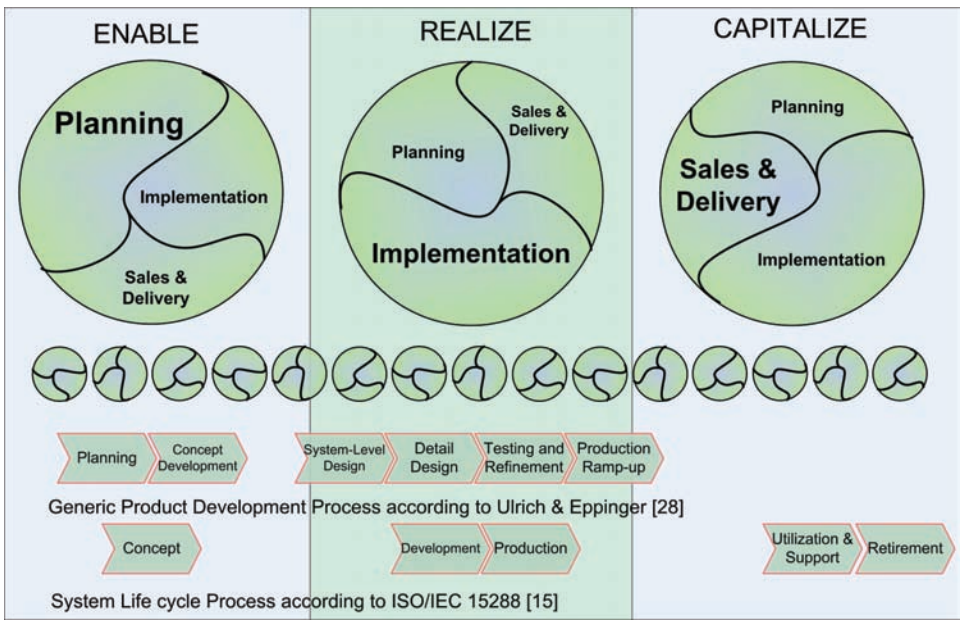

Figure 4. A possible mapping is illustrated between the conceptual performance evaluation framework and system life cycle phases, based on activity categories and phases in two different product development processes [15, 28]. The low level activity based evaluation is performed interchanging and continuously over the life cycle.

Performance evaluation affects different aspects of product development. As a consequence of using a holistic approach in the process of developing the framework from a system perspective, three uniting perspectives have emerged: integrated, information and learning. Integration and Information are both cross-boundary and relevant to the system overall, and are necessary in order to accomplish performance evaluation. Learning is important in order to assimilate the results in the organization; otherwise the use of a performance evaluation framework will be non-value adding.

3.1 Integrated Perspective on Performance Evaluation

It is important to acknowledge that different capabilities are needed in product development, and that, in order to be successful in a company perspective, high performance is needed in every phase [2]. Evaluation of different performance activities needs to be made to increase the level of overall existing performance, but in order not to sub-optimize the intended measurements, it is argued that the different enablers (input, output, goal and recourses) should not be evaluated individually since they are not independent from each other. The same reasoning, can be applied to the different activities, and used for the overall product development to make sure that people work together and interactively. The framework allows modeling on different levels of abstraction, and high system level modeling should be used to help companies evaluate whether product development is being carried out in an integrated way. The need for integrated product development is well established in industry, and the existence of integrated product teams and cross-functional integration is crucial in large organizations where knowledge-intensive products are developed. Different types of integration (such as process, competence, and multi-project) are needed to gain an effective product development process [29]. In this research, it is argued that the same understanding and integrated perspective should be reflected when it comes to choosing the type of measurements for different activity categories. Moreover, the overall product development system – comprising of organization, process and product [30] – that is used to enable development activities needs to be evaluated, since this is often more complex than the products themselves. An integrated perspective on performance evaluation assists companies to evaluate to what extent they succeed in their ability to perform integrated product development.

3.2 Information Perspective on Performance Evaluation

The need for accurate information becomes crucial to make use of the activity model, and accomplish the steps in the suggested framework; the identification of improvement areas and the mapping of relevant performance metrics (*Figure 3*). Information is considered an important role for success in product development outcomes. Sink and Tuttle [12] argue that the main focus of the performance measurement system is to provide managers with the needed information to be able to make decisions about what actions to take in order to improve the performance of the organization. From a designer perspective, cross-functional integration is important to support efficient information management [31] and the framework might be one aid in making this need explicit to a designer, to communicate and exchange information internally and externally from the company. One possibility might be to use an information strategy based on activity modeling, to actively increase performance. Further research needs to be done on what precondition that have to be fulfilled in order to do so.

A discussion about what the information consist of – based on defining what the input and output is, and what information needs to be transformed – supports an increased understanding in the organization of what it is relevant to measure, and aids the design of metrics so that they produce relevant information. It is argued that by questioning the state of information and "giving" it precise meaning and relevant content, the way information is presented becomes more well-defined. From a system perspective, companies could clearly benefit from an increased use of a homogenous terminology between the different areas in the product development organization. It is suggested that one synergy derived from using the framework and "modeling process" would be a terminology alignment across the different engineering disciplines and organizational functions, since the reuse of terminology between the different categories of activities supports this standardization towards a uniform use.

3.3 Learning perspective on Performance Evaluation

The need for measuring the performance of product development activities differs between different organizations. Drucker [32] argues that the single greatest challenge that managers face is to raise the performance of knowledge workers. It is important to acknowledge that performance measurements are not in themselves raising the performance level (i.e. a value creating process). Value is only achieved when the performance evaluation system is used as a first step in an improvement process. It is only when the decided improvement actions have been implemented that value might have been created in a company perspective. This is in line with what Neely and Najjar [33] argue for – namely that the true role of performance measurement is to provide a means of management learning, rather than simply a means of management control. It might be a little strong to say that today's upper management tend to use the measurements for control purposes, but it is appropriate to say that there needs to be a more internal learning perspective as well to better balance the control perspective.

The popular New Sales Ratio [34] can be used to illustrate how management learning can be achieved through performance measurement. This performance indicator can be useful as a measure of product development effectiveness – i.e. is the revenue generated as anticipated in the business case, once the products has been developed and introduced to the market? The business case is commonly merely used as a way to get the OK to initiate the development of a new product. The anticipated new sales revenues are often estimated with the objective of initiating the project and from there on it is taken for granted that the new products will generate value to the company. This could instead be used and managed in a learning perspective, in order to improve the ability of creating business cases: are the important aspects of the product created in the implantation activities? are the sales and delivery activities able to communicate the important selling aspects of the new product? It is important that the planning, implementation, and sales and delivery activities support each other and constantly contribute to better estimations and a common understanding of what is important in order to be successful from a systems perspective.

4 CONCLUSIONS

One issue with the current way of evaluating performance in product development is that focus is on what is measurable, instead of on what it is important to measure. Focus tends to be on the end result of the development project and the outcome of that result. A holistic performance evaluation framework for complex product development is presented to provide people involved in product development activities with a better understanding of performance relevance. The framework is intended to be used to help companies realize in what situations the development process is working, and where it is not working, and to identify improvement areas.

The proposed holistic performance evaluation framework explicitly integrates the goal and objective with the product development. Planning activities have been incorporated into the framework in order to support the idea that the relevance of performance evaluation is continuously coupled to company strategies and goals, avoiding measurement for the measurement's sake. The framework is intended as a company or management tool for communicating an integrated view on performance in product development, but also as evaluation support for the individual (e.g. a designer) conducting a particular activity, in order to relate how this particular activity contributes to the overall performance of the product development process. The presented framework contributes with performance criteria that help companies in complex product development settings to identify relevant qualitative and quantitative metrics that are system dependent. By focusing on which factors are important to measure, this framework can be used to design new measures or identify relevance among existing measures. The presented framework is conceptual and intended to be tailored to suit the individual company's needs, but the following list summarizes the most important and generic contributions of this paper:

- Support for making performance criteria more explicit
- Classification of planning, implementation, and sales & delivery activities
- Internal company support for performance measurement
- Promotion of a system thinking approach to the performance evaluation task
- Evaluation tool for activity value assessment, process and product independent
- A framework for companies to develop their adapted performance evaluation system

5 CONCLUDING REMARKS

At this stage, the framework is conceptual and has not been applied in practice. Future research needs to be done in order to test and evaluate it further. The presented framework will be refined and developed with the aim to provide stakeholders in complex product development settings with an evaluation tool to better understand and grasp the complexity of performance measurement. It is argued that this will have implications on how values such as efficiency and effectiveness in product development are evaluated by management. The first step in this work will be to apply the performance evaluation framework in a large organization developing complex industrial products in Sweden. The aim, besides testing the framework, will be to use performance activity modeling as a base for deriving performance measurements for the early phases of the product development and relating them to the activities performed in the actual development projects. This work will be conducted during autumn this year, and will be carried out through a number of workshops activities following the four steps to accomplish performance evaluation as described in Figure 3.

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REFERENCES

1. Neely, A., *The evolution of performance measurement research: Developments in the last decade and a research agenda for the next.* International Journal of Operations & Production Management, 2005. 25(12): p. 1264-1277.
2. Goffin, K. and R. Mitchell, *Innovation Management: Strategy and Implementation Using the Pentathlon Framework*. 2005, London: Palgrave MacMillan.
3. Godener, A. and E. Soderquist Klas, *Use and impact of performance measurement results in R&D and NPD: an exploratory study.* R & D Management, 2004. 34(2): p. 191-219.
4. Haffy, M.K.D. and A.H.B. Duffy. Process Performance Measurement Support: A Critical analysis. in *International Conference on Enginering Design*. 2001. Glasgow, UK.
5. Govindarajan, V. and P.K. Kopalle, *The Usefulness of Measuring Disruptiveness of Innovations Ex Post in Making Ex Ante Predictions*.* Journal of Product Innovation Management, 2006. 23(1): p. 12-18.
6. McGrath, M.E. and M.N. Romeri, *The R&D Effectiveness Index: A Metric for Product Development Performance.* Journal of Product Innovation Management, 1994. 11(3): p. 213-220.
7. Driva, H., K.S. Pawar, and U. Menon, *Measuring product development performance in manufacturing organisations.* International Journal of Production Economics, 2000. 63(2): p. 147-159.
8. Chiesa, V. and C. Masella, *Searching for an effective measure of R&D performance.* Management Decision, 1996. 34(7): p. 49-57.
9. O´Donnell, F.J.O. and A.H.B. Duffy. Performance Management at Design Activity Level. in *International Confernce on Engineering Design*. 2001. Glasgow, UK.
10. Marchand, M. and L. Raymond, *Researching performance measurement systems: An information systems perspective.* International Journal of Operations & Production Management, 2008. 28(7): p. 663-686.
11. Neely, A., M. Gregory, and K. Platts, *Performance measurement system design: A literature review and research agenda.* International Journal of Operations & Production Management, 2005. 25(12): p. 1228-1263.
12. Sink, D.S. and T.C. Tuttle, *Planning and Measurement in your Organization of the Future*. 1989, Norcross, GA: Industrial Engineering and Management Press.
13. O'Donnell, F.J. and A.H.B. Duffy, *Modelling design development performance.* International Journal of Operations & Production Management, 2002. 22(11): p. 1198-1221.
14. Colquhoun, G.J., R.W. Baines, and R. Crossley, *A State of the Art Review of IDEF0.* International Journal of Computer Integrated Manufacturing, 1993. 6(4): p. 252-64.
15. Haskins, C., *Systems Engineering Handbook*. 3 ed. 2006.

16. Griffin, A. and A.L. Page, *PDMA success measurement project: Recommended measures for product development success and failure.* The Journal of Product Innovation Management, 1996. 13(6): p. 478-496.
17. Loch, C., L. Stein, and C. Terwiesch, *Measuring development performance in the electronics industry.* The Journal of Product Innovation Management, 1996. 13(1): p. 3-21.
18. O'Donnell, F.J. and A.H.B. Duffy, *Design Performance*. 2005, London: Springer Verlag.
19. Davila, T., M.J. Epstein, and R. Shelton, *Making innovation work - How to manage it, measure it and profit from it*. 2006, New Jersey: Wharton School Publishing.
20. Hubka, V. and W.E. Eder, *Design Science*. 2 ed. 1995, Berlin: CRC Press.
21. Johnsson, S., J. Eriksson, and R. Olsson. Modelling performance in complex product development - A product development organizational performance model. in *The 17th International Conference on Management of Technology*. 2008. Dubai, U.A.E.
22. Peters, T., *Tom Peters revisited: What gets measured gets done.* Office Solutions, 2002. 19(9): p. 32-33.
23. Hauser, J. and G. Katz, *Metrics: you are what you measure!* European Management Journal, 1998. 16(5): p. 517-528.
24. Gharajedaghi, J., *Systems Thinking: Managing Chaos and Complexity - A Platform for Designing Business Architecture*. 2 ed. 2006, San Diego: Elsevier Inc.
25. Kerssens-van Drongelen, I.C., B. Nixon, and A. Pearson, *Performance measurement in industrial R&D.* International Journal of Management Reviews, 2000. 2(2): p. 111-143.
26. Johnsson, S., *Performance and Performance Measurements in Complex Product Development*, in *School of Innovation, Design and Engineering*. 2008, Mälardalen University: Västerås.
27. Reber, M. and A. Duffy. Value Centered Design: Understanding the nature of value. in *International Conference on Engineering Design*. 2005. Melbourne, Australia.
28. Ulrich, K.T. and S.D. Eppinger, *Product design and development* 3ed. 2003, Singapore: McGraw-Hill Education.
29. Engwall, M., J. Forslin, M. Kaulio, M. Norell, and S. Ritzén. Engineering Management for Integration. in *International Conference on Engineering Design*. 2003. Stockholm, Sweden.
30. Eppinger, S.D. and V. Salminen, *Patterns of product development interactions*, in *Proceedings of International Conference on Engineering Design - ICED 2001*. 2001: Glasgow.
31. Malvius, D., *Information Management for Complex Product Development*, in *Machine design*. 2007, KTH: Stockholm.
32. Drucker, P.F., *The New Productivity Challenge.* Harvard Business Review, 1991. 69(6): p. 69-80.
33. Neely, A. and A. Najjar Mohammed, *Management Learning Not Management Control: THE TRUE ROLE OF PERFORMANCE MEASUREMENT?* California Management Review, 2006. 48(3): p. 101-114.
34. Whitley, R., T. Parish, R. Dressler, and G. Nicholson, *Evaluating R&D performance using the new sales ratio.* Research Technology Management, 1998. 41(5): p. 20-22.

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