The evaluation of manufacturing issues in the product development process

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Abstract

Many companies still do not achieve the success rates they desire with new product introductions to the market. A method has been developed to aid companies to self-evaluate their product development processes. The method meets an identified need for a non-prescriptive procedure to evaluate an existing or proposed product development process at a detailed level, both in the context of the company's own products, processes, procedures and markets, and in the context of accepted good practice.

The specification and development of the process and facilities needed for the manufacture of a product are identified as fundamental generic issues within the product development process that must be handled effectively to achieve successful product outcomes. The paper describes the main constructs of the evaluation method in relation to manufacturing issues, and presents results and findings from trials conducted in industry. It is seen that great care is needed to ensure that company practitioners make objective assessments of the important factors. Further work is planned to develop the method as an interactive computer tool and to conduct more trials.

Keywords: New product development (NPD), Product development process (PDP), Manufacturing

1 Introduction

It has been recognised for some time that successful new product development (NPD) is crucial for the survival of manufacturing companies [1], and therefore important to the economy of industrial countries. However, many companies still do not achieve the success rates they or their governments desire [2, 3, 4]. It therefore remains important to conduct research in this field with a view to enabling companies to improve their NPD success rates.

Research on NPD has been ongoing for about 4 decades. Some companies have gained advantage from the research but by no means all [3]. In the main, advantage has been gained by large companies that have been able to invest significantly in management systems. Smaller companies may have complex products, company structure and information flow, but are limited in the investment that they can make. However, there is no reason why existing management knowledge should not be available to all companies. One approach is to employ management consultants. This makes available a broad based knowledge and experience of management and design theory and methods. However, the cost can be high and companies often find that they cannot, or do not, implement the full recommendations [5, 6]. Some internal resistance to external management systems and consultant recommendations can exist due to the 'not-invented-here' syndrome.

What is needed is a less expensive and more focused approach. The authors [7] have argued that the most effective way for a company to develop its product development process (PDP), including manufacturing and supply process requirements, is to do so in house. The aid of methods and tools to ensure that it is done in a rational way and in the context of current management theory will make the outcomes more likely to be both relevant and realisable. To address this need, a non-prescriptive self-assessment method has been developed [7] to assist companies to evaluate their current (or proposed) PDP. The structure of the method clarifies the complexity of the PDP and enables a company to utilise its own knowledge about its products, processes, procedures, and markets while still relating the evaluation to NPD management good practice. This provides a lower cost approach related to the unique requirements and capabilities of the company, and encourages companies to evolve their own PDP in a learning environment.

The evaluation method enables companies to make their own judgements of the relative importance of particular elements of their PDP to successful product outcomes, and to estimate the effectiveness of these elements. This paper examines in particular those elements of the PDP that relate to the manufacture and supply process, and reports on progress with evaluating these with the aid of the method.

2 Outline of the method

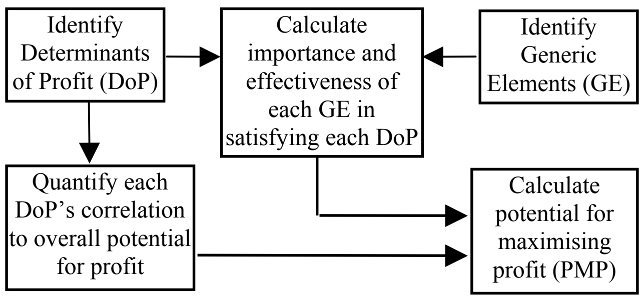

Figure 1. Structure of the PDP evaluation method

A number of studies over the years have identified effective execution of particular activities within the development process as critical to new product success [8, 9, 10]. In recognition of this, the evaluation method requires companies to model their PDP in terms of its activities, and then to evaluate the effectiveness of each activity in addressing the important product issues. The evaluation method is based on a framework that seeks to represent all the mechanisms and influences that come into play in realising profits through manufactured products, and is structured as shown in Figure 1 [7].

The company is asked to identify important features of their products and services that must be addressed in the PDP, and to estimate their correlation to successful product outcomes. These features are viewed as the determinants of profit (DoP). The specific company activities that execute the PDP are sorted under eighteen generic elements (GE), such as 'prepare project proposal', 'design product', 'specify supply processes' and 'develop new supply resources'. The correlation between the effective execution of the GEs and the successful realisation of each DoP (i.e. the impact of each GE on each DoP) is elicited from expert company practitioners. The company is guided through an evaluation process that enables quantified estimates to be made of the effectiveness of the activities under each GE, and hence of the effectiveness of the planned implementation of the PDP. Companies can use the method at a detailed level to evaluate the effectiveness of each activity in addressing a particular DoP, or at a more general level to evaluate the activities for their effectiveness in realising the overall product. An analysis of the data produces an overall quantified measure of the potential to maximise profits (PMP) from products produced by the PDP, together with a profile of the important aspects of the PDP and its effectiveness in handling those aspects.

A key element of the method is to be able to quantify the effectiveness of each PDP activity in addressing the issues identified by the DoP. The approach adopted is to assign a number of characteristics (such as setting of objectives, resources made available, input data) to the activities. An expert practitioner then judges the quality of these characteristics in the context of addressing the issue raised by each DoP (or more generally in the context of the whole product) and, on the basis of these judgements, makes an estimate of the effectiveness of the activity.

The method provides a critical review of the quality of the company's PDP using quantified judgements based on knowledge about the company's processes, products, culture, markets, customers, etc. Although the evaluation is performed in the context of current good NPD practice, the method will handle any form of PDP and is not simply a comparison with a prescribed procedure.

3 Research Method

The basis of the evaluation method was devised after a review of existing methods, and its main constructs worked out in some detail. These were then tested and developed through collaboration with industry to ensure industrial relevance. A number of surveys and trials were carried out in industry. These were used to shape and test the method, to ensure that company practitioners could relate to the new concepts used in the method (e.g DoP, GE, activity effectiveness), and to assess the degree to which they felt that the method allowed them to express their knowledge about their products and processes.

Initially, a postal survey was undertaken in which 132 survey forms were sent to senior managers (e.g. managing directors, technical directors, engineering directors) of manufacturing companies that undertake their own product design and development. A total of 27 questionnaires were returned from companies over a wide range of industrial sectors e.g. medium volume hi-fi equipment, low volume large marine equipment and large machine components, high volume electronics, medium volume vehicle systems, medium volume filtration systems. Later on, trials were carried out with a group of eight companies that collaborated directly in the research programme to test parts of the evaluation method, and finally the complete method was tested by the researcher working directly with an expert company practitioner in three companies. Company 1 manufactures heavy marine equipment. Company 2 produces medium volume computer parts, and company 3 produces audio equipment for the commercial and consumer markets.

These tests and trials have been discussed in detail elsewhere [7, 11], but a substantial amount of data about industrial company products and processes was obtained, and that relating to manufacturing issues is presented in the following sections.

4 Manufacturing and Supply GE

The list of GE was created by developing a model of the PDP based on the IDEF0 modelling structure [12]. The model is based on an expansion of all the execution and control functions of a company that impinge on the PDP. The IDEF0 structure is well suited for this purpose, and has been used in a similar manner, for example, by Harrington [13] to produce a generic model of a manufacturing enterprise, and by Ang, Luo and Gay [14] to produce a generic model of the metal cutting industry that company experts can use as a start point to establish company specific models. The development of the model and the full list of GE are described by Fairlie-Clarke and Muller [15]. The GE that relate directly to manufacture/supply issues are listed in Table 1, together with some typical activities that might be used by a company to implement each GE. The purpose of these activities is to ensure that the product as designed can be manufactured, delivered, and supported in the market.

Table 1. Supply and manufacturing GE, and strength of focus

GE Constituent activities	Company: 1	2	3
GE11 Specify Supply Processes Manufacturing process planning/design. Generate manufacturing drawings. Define sourcing of parts and materials. Approve/qualify suppliers. Generate procurement specifications. Generate manufacturing specifications. Write quality plan. Plan production and distribution.	0.02	0.17	0.09
GE12 Develop New Supply Resources Develop plant and factory (staff and facilities). Provide jigs and tools etc. Develop sales organisation. Develop distribution organisation. Develop support organisation.	0.06	0.06	0.09
GE13 Evaluate and Approve Supply Development (not evaluated during trials)			
GE18 Execute Product Launch Set up supply process to handle product (e.g. sales, orders, contracts, purchase, manufacture, distribution, and support). Ramp up to manufacture.	0.04	0.05	0.01
Total focus on manufacturing issues	0.12	0.28	0.19

The strengths of focus that the three companies estimated they had on the manufacturing and supply GE are indicated by the numbers on the table. These numbers are normalised so that the total focus on all GE is equal to 1.0. They can be put into perspective by comparison with the focus that the companies have on the GE 'Design product', which was rated highest by each of the three companies at 0.10, 0.17 and 0.26 respectively.

“Specify supply processes” is rated high by Company 2, but otherwise each supply and manufacturing GE is rated significantly lower than the design GE. However, the companies all have a good awareness of product development issues, and their total focus on manufacturing and supply issues during development is of the same order as their focus on design, except for Company 3 where the lower focus on manufacture may have resulted in a reduced profitability of the product under review (see Section 6).

It became apparent from an analysis of the trial results that the company practitioners tended to rate their focus as high on the activities that caused problems, and lower on activities that generally ran smoothly. The danger of this is that these activities will then be rated as unimportant in the PDP evaluation, in which case potential problems, or areas for improvement, will not be exposed. The importance of an activity is best estimated by considering what the consequences would be if it was not handled successfully, no matter how easy it might be to get right.

Another important issue is that design problems will almost certainly be recognised as problems with the PDP, whereas a failure to properly address the manufacturing and supply issues during product development may not become evident until manufacture commences, and may then be seen as a supply problem. The development of the supply process must be seen as much a part of the PDP as design of the product.

5 Determinants of Profit (DoP)

During the survey, respondents were asked to identify some DoP for a nominated product. About 6% of the DoP that were identified by companies in the survey were supply related, and these are shown in Table 2. The respondents were also asked to rate the degree of importance of each DoP on a scale of 1 (low importance) to 5 (high importance).

Table 2. Manufacturing and supply DoP results from survey

DoP	Degree of Importance
Comply with standard sizes etc.	5
Zero defects at installation	5
Finish and appearance	4
High build quality	5
Parts availability	5
Good spares availability	5
Manufacturability	4
Low cost of manufacture / supply	5
Good manufacturing process for volume manufacture	5
Low development cost	5
Cost of ownership	4
Competitive price	5
Ease of assembly	4
Ease of manufacture	5
Available on short delivery	4
Effective supplier outlets	5
Good delivery performance	5

The high rating given to these DoP indicates that it is crucial that they be addressed effectively during development of the product, and highlights the important role that activities related to manufacture and supply play in achieving product success.

6 Activity/GE effectiveness

The evaluation of the PDP is undertaken by estimating the effectiveness with which every activity is performed [11]. Judgements about activity effectiveness are made by company experts in response to questions that reflect current NPD good practice in terms of quality of solution, timeliness and resource utilisation. The method can be applied at a detailed level by making these judgements in the context of each DoP, or more generally (and quickly) in the context of the whole product. The advantage of considering each DoP is that the user is forced to give attention to particular issues. For example, if a launch date is critical, then timely consideration of manufacturing and supply issues must feature in the PDP.

The list of GE ensures that the company gives consideration to what manufacturing and supply development activities may be necessary, and evaluates how effectively these are handled and whether they are addressed at the optimum time during the process. The procedural nature of the method brings to the attention of the company all the issues that are likely to affect the product outcomes, and ensures that issues, which in the past may not have been considered in detail if they were not seen as problem areas, are not overlooked in the evaluation. It is easy to assume that the problem areas are the only important issues, but this may not be the case. Important issues may have been handled well in the past and caused no problems, but their importance must be recognised in the evaluation, lest one day they become the problem area.

The effectiveness of activities that impact on important DoP is of major importance in maximising the potential for profit. Decisions must be made about the manufacturing process and the manufacturing facilities to be used (and developed if necessary). These decisions must be made at a time when any impact on the product design can be accounted for in an interactive manner, and that will allow the product to be launched as planned. The necessary resources must be available and controlled to enable the activities to be completed in a cost effective way. Cross functional interactions must be used to effectively resolve the manufacturing and supply issues during product development. Song, Montoya- Weiss and Schmidt [16] identify the most direct effects on cross-functional performance as stemming from the company's evaluation criteria, reward structures and management expectations. Their findings show that the use of an internal facilitator is beneficial, and that it is management action rather than environment that determines the degree of co-operation achieved.

The method used to assess the effectiveness of each activity must be able to address factors of this type. As described earlier, the method requires the company to review the characteristics of each activity in the context of current good practice, and then to make a quantified estimate of the quality of the characteristics in the context of each DoP. The characteristics define the manner in which a company handles an activity in terms such as objectives set, people employed, resources available, information available, evaluation of outputs. There are a wide variety of characteristics that have different effects on the successful performance of the activity, so a framework is helpful to focus attention on a particular category of characteristics at a particular time. In keeping with the ethos of the PDP evaluation method, the activity assessment procedure must be universally applicable to all activities identified under the generic PDP model. The model was developed using a function expansion according to the rules of Softech's IDEF0 modelling structure [12]. This structure is illustrated in Figure 2, where the PDP activities are represented by the function box, and the input, controls and means act as constraints on the activity, in that each must be satisfied before the output can be produced. These constraints were not used to create the generic model, but they provide a good structure for categorising the characteristics of the activity.

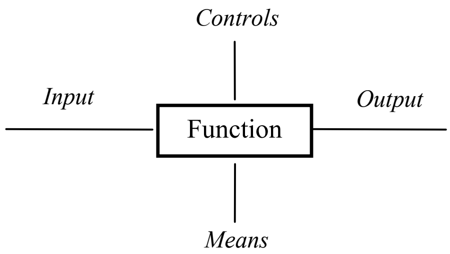

Figure 2 IDEF0 Task Structure

Characteristics are assigned as follows:

The input is data that describe the state of the product, and which are added to or transformed by the activity. E.g. ideas, proposals, specifications, concept sketches, detailed drawings, models, prototypes, launched products. The input may include geometrical and material data, performance data, cost data and manufacturing process data. With this definition, the materials to build a prototype are defined as a ‘means’ to transform a design from a drawing to a solid artefact, and are not considered as inputs to the activity, as they would be in a manufacturing process. The input characteristics describe, for example, the scope of the data, its completeness, its accessibility and it reliability

Control characteristics describe the objectives, instructions, conditions, circumstances, influences, information and monitoring that govern the activity and they show why, when, to what standards, etc. the activity is to be, and is being, executed. Every activity will have at least one control.

Means are the people, facilities, equipment and materials that are necessary to carry out the activity. The characteristics relate to the identification, availability, quality and management of these resources.

'Output' is not used to characterise the activity. The output is the consequence of the activity, and the view is taken that high quality output will result when the other characteristics, on which output is dependent, are such as to promote effective execution of the activity. There are many measures of the quality of the output of PDP processes, but these can only provide retrospective information. However, an effective activity will include amongst its ‘control’ characteristics procedures for monitoring and evaluating the quality of its output prior to delivering that output. The output of one activity will often form part of the input to subsequent activities. The manner in which the output is made available to subsequent activities, and the degree to which the output satisfies the needs of the subsequent activities, will form part of the assessment of the input characteristics of the subsequent activities.

The user of the evaluation method is encouraged to review the characteristics of each activity in the context of current good practice. This context is provided in the form of questions that are put to the user under each category of characteristic and for each category of DoP (see Table 3). The aim of the questions is to prompt the user to adopt a critical and informed view of the companies own practices before making a judgement of the effectiveness of the activity. This process provides an interesting mechanism for delivering good practice knowledge to companies in a non-prescriptive way and in the context of their own operations. The example in Table 3 is kept simple to fit the space, but some further good practice issues relating to the process of defining the manufacturing and supply requirements of a new product are summarised in Appendix 1. This is not an exhaustive list of good practice, and an important aspect of developing the PDP evaluation method is to develop these lists and to customise them for different market sectors and different types of development (e.g. incremental or innovative). Companies may also wish to add questions reflecting their own good practice beliefs prior to carrying out the evaluation of their PDP.

Table 3

Good Practice Matrix
Activity: Generate manufacturing drawings

DoP Category	Good Practice Category: Input	Control	Means
Quality of solution	*Is geometry finalised?*	*Are standards defined?*	*Is CAD available?*
Timeliness	*Is a start date defined?*	*Is progress monitored?*	*Can target date be met?*
Resource utilisation		*Are resource needs planned?*	*Is performance benchmarked?*

The assessment of the effectiveness of activity execution is very much concerned with looking at company organisation, human, equipment and information resources, and project management. These aspects are deliberately kept separate from the PDP activity model so that management activities such as team building, scheduling and review do not become confused with the added value activities that define the product. The performance of the added value activities will only be effective if mechanisms are in place to ensure, for example, that the necessary skills are available in the development teams and that appropriate levels of concurrency of activities are employed.

Results showing the effectiveness of manufacturing and supply activities, as estimated by the three companies during the final trials are summarised in Table 4. The most striking feature of these results is the high effectiveness values estimated for the activities of Company 3. The confidence that the practitioner has in the company’s processes is a consequence of the success of their products. However, one must be careful about using this as a basis for evaluation. Success is always a retrospective measure of a process that has been used in the past, and circumstances may change. The product requirements may be different, competition may increase, staff and facilities may change. A process that has been successful historically may have been reliant on informal methods that will not adapt to change. The estimates of effectiveness should therefore be based on a good understanding of the characteristics of the activities, not on their past success (although this will be an indicator).

Table 4
Activity effectiveness for manufacturing and supply activities

GE	Company 1	Company 2	Company 3
GE11: Specify Supply Processes	0.55	0.70	1.0
GE12: Develop New Supply Resources	0.56	0.70	1.0
GE18: Execute Product Launch	0.68	0.82	1.0

Further investigations showed that in fact the activity effectiveness in Company 3 was not as high as estimated. During the development of the product the company realised that they could not manufacture the product in house and also meet their financial objectives. They therefore decided to outsource the manufacturing. However, by the time this decision was made, the amount of rework that was necessary resulted in a missed product launch date (an annual exhibition), and the launch was postponed by a year. Fortunately, the product performance has exceeded expectations, but more effective, and earlier, consideration of the manufacturing requirements could probably have avoided the delay. Had the PDP evaluation method been applied prior to the development of the product, a DoP such as 'launch at annual exhibition' would have been identified and would have focussed attention on the timely execution of the GE 'specify supply processes'.

7 Conclusion

The findings from the trials indicate that the evaluation method returned results that all industrial practitioners thought accurately reflected the capabilities of their respective PDPs. The computer component practitioner observed more than once that the evaluation method had encouraged him to think about issues that he would normally take for granted. The audio system practitioner observed that he found the PDP model to be 'very comprehensive' and noted that it helped him to crystallise in his mind what is generally done but often not thought about. Both suggested that obtaining inputs from experts in other company functions (marketing, design, management, manufacture, etc.) would help to identify a fuller set of DoP.

A design objective for the method was that it should provide an in depth focus on the activities of the PDP and on their effectiveness in relation to their impact on successful product outcomes. Results show that even though the method was somewhat truncated during the trials due to time constraints, the procedure was executed without difficulty and resulted in meaningful quantification of PDP effectiveness.

Another objective was that the method should enable companies to judge the relative importance of particular elements of the PDP to successful product outcomes. Findings indicate that all practitioners were able to make judgements about the relative importance of each of the DoP and each of the activities, either by using pair wise comparisons, or by grading against a scale of importance. Practitioners judged manufacturing related DoP as having high degree of importance. Manufacturing related GE and activities were generally rated as being of medium importance, but the total focus was quite strong. This trend may be attributed to the fact that the practitioners believe these activities to be executed with some proficiency in their processes. In future trials it may be more informative to elicit judgements about the relative importance of activities by considering the consequences if they are not executed effectively.

In all trials, the collaborators were satisfied that the computed potential for maximising profits (PMP) was a fair reflection of the effectiveness of their PDP. The trials to date have deliberately tested the method on existing PDPs so as to be able to compare the PMP value with the success in the market place of products produced using the PDP as evaluated. The main purpose of the evaluation method is to assess the potential of proposed PDP, and further trials are now required to test the method in this mode. To allow more extended and extensive trials it is important that the method be implemented as an interactive computer tool with embedded expert knowledge. Users with a good awareness of PDP issues will then be able to use it without the aid of a facilitator.

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8 Appendix 1

Quality of Solution

Input

Is the input data complete?
Is the data in a re-usable form?
Are the requirements for data defined?
Is the input data checked?
Is the status of product data controlled?

Control

Are activity objectives well defined and understood by all involved?
Is understanding of objectives tested?
Is the way in which the outputs of the activity will be used available as a control on this activity?
Are the performance of the activity and its results formally monitored and reviewed in relation to the objectives?
Does feedback occur, and is the process adjusted as necessary?
Does the organisation and structure promote effective execution of the activity?
Is a facilitator used for cross-functional activities?
Do formal change mechanisms exist?

Means

Are resource requirements for the activity identified, reviewed and agreed?
Do the staff executing the activity have the right expertise, knowledge, experience and motivation?
Are the right people doing the right jobs?
Are cross-functional teams used?
Is the necessary information (e.g. technology, standards, market, materials) made available?
Is the information utilised effectively?
Are the necessary facilities, equipment and software tools available?

Timeliness

Input

Are input requirements included in the schedule?
Do mechanisms exist to flag missing inputs?
Is there early warning of delays to input data?
Does activity start immediately the inputs are available?
Can assumptions be made about the inputs to the activity that would enable an earlier start?

Control

Are formal project management methods used?
Do mechanisms exist to determine whether the activity objective is achievable within the time allotted? Are they used?
Is the impact on profit of late/early completion known?
Is the time required to perform this activity benchmarked against industry standards, competitors etc.?
Is a completion date set for this activity?
Is elapsed time continuously monitored relative to progress?
Are corrective actions taken to reduce delays?
Is this activity dependent/interdependent on others in terms of input data, information, resources, tools, facilities, etc.?
Has the cause of this dependence/interdependence been determined (e.g. information, resources, tools, facilities)?
Is it possible to remove the cause of dependence/interdependence (e.g. more money, more staff, new tools, restructuring, teams) to allow concurrent execution?
Can activities that are traditionally sequential be made to interact and therefore be performed concurrently?

Means

Are available resources identified, agreed and allocated in good time?
Are training requirements identified early?
Are information requirements identified early?
Can resource capacity be increased rapidly?
Do mechanisms exist for identifying and evaluating alternative methods/resources to reduce time scale e.g. buy-ins, sub-contract, consultants, software tools? Are these mechanisms utilised?

Resource Utilisation

Input

Are input requirements defined so as to minimise any rework?
Do upstream activities know how their data will be used?

Control

Is resource utilisation monitored against budget and progress?
Do contingency plans exist for loss of key personnel and failure of key systems?
Is staff loading and performance monitored?
Do mechanisms exist to match resource loading to resource capacity? Are they used?
Do mechanisms exist for cost/benefit analysis of added resource? Are these utilised?
Is resource consumption benchmarked?

Means

Are staff and teams located effectively?
Is information provided in a readily useable form?
Are the necessary resources provided at the right time?
Do mechanisms exist to match the allocation of resources to the objectives of the activity? Are they used?