Manufacturability evaluation in early design: On the dependency of business commitment

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Abstract
As business-to-business manufacturers move towards higher business commitments, such as providing functions instead of transacting physical artefacts, new challenges arise when manufacturers strive to adapt and integrate the development of physical artefacts to the function to be provided. Since manufacturability evaluation is a part of development, it is feasible that it will also face new challenges. However, studies on the relationship between business commitment and manufacturability evaluation are lacking. In this paper the hypothesis "*manufacturability evaluation depends on the business commitment*" is initially tested, and results from studies at a manufacturer within the Swedish jet engine industry are presented. Business commitments range from make-to-print through to the development of physical artefacts for transaction towards the development of function-focused total offers. Results indicate that some work methods for manufacturability evaluation are affected, since business commitments change, to ensure that design teams make right decisions, according to, for example, planned contractors and company capacity and capability during early development.

Keywords: Manufacturability evaluation, business commitment, early design, design support, functional product development.

1 Introduction

The development of hardware often includes a continuous iteration of synthesis and analysis where, e.g., the dimensions and tolerances are defined for the physical artefact and then evaluated for manufacturability. The jet engine industry has numerous business commitments ranging from contractual manufacturing through to traditional development and sell-off towards total offer or functional products. Functional product development focuses on how hardware can be developed to fit the goal function (Alonso-Rasgado et al., 2004; Ericson, 2006). Because different business commitments often have different collaborative arrangements, it would be feasible to assume that development, in general, or manufacturability evaluation, in particular, would be affected by a change in collaborative arrangement. Manufacturability evaluation coupled with design has been in focus for a long time (Boothroyd et al., 2001; Shehab and Abdalla, 2001). There is, however, a lack of work dealing with the issue of dependency between manufacturability evaluation and business commitment. To develop competitive products on the global market it is important to know what process for manufacturability evaluation to follow at a certain business commitment. This paper presents some initial findings from a study at a Swedish jet engine manufacturer, where the hypothesis "*manufacturability evaluation depends on the business commitment*" is initially tested.

2 Relevant literature

2.1 Functional product development

Some manufacturers are initiating work towards a service-based product – product-service system involving more business commitment than a traditional transaction of an artefact (Mont, 2002). Focusing on how the artefact, which will be used in the service, should be developed to give a win-win situation for the customer and the manufacturer turns the spotlight to functional product development (FPD) (Alonso-Rasgado et al., 2004; Ericson, 2006). Alonso-Rasgado et al. present issues to focus on when developing service support systems for functional products (Alonso-Rasgado et al., 2004). Ericson describes the importance of a shift in view on a business level, from hardware to service, and an integration view on the product development level (Ericson, 2006). This shift in view on the business level sets new flexibility requirements for the product development level, since collaboration with other function providers is needed.

2.2 Manufacturability evaluation

Most work on manufacturability evaluation focuses on how to design a manufacturable product. Boothroyd et al. describe methods and heuristics for how a product definition is made manufacturable at a feasible cost by minimizing the number of parts and employing, for example, early cost estimation (Boothroyd et al., 2001). Computer applications for automated manufacturing prediction in terms of cost and capability are also common, some examples are (Ramana and Rao, 2005; Shehab and Abdalla, 2001).

2.3 Linkage between business and technology strategies

Many papers describe the importance of integrating business, design and manufacturing functions, which is the theme of integrated product development (Andreassen and Hein, 1987). Gupta and Lonial argue that a business strategy has an impact on the manufacturing strategy (Gupta and Lonial, 1998), though design evaluation strategy is not highlighted. Simonsen shows that functional analysis can be used to ensure that the design activity follows the overall business strategy (Simonsen, 1997), but manufacturability evaluation is not focused. Therefore there is a need of research investigating the linkage between business commitment and manufacturability evaluation.

3 Study

A study at a Swedish jet engine manufacturer was conducted to acquire data about development, in general, and manufacturability evaluation, in particular, for different business commitments. Five open-focused interviews were conducted by telephone with three persons involved in the business offer function, product development and production at the manufacturer. Results from a workshop with the manufacturer, represented by eight staff members and that followed the future workshop model, were used as input to formulate questions for the open focus interviews and for the discussion in this paper.

4 Findings

This section presents the findings from the study regarding the level of business commitments and work methods for manufacturability evaluation during early design. Issues from the study concerning manufacturability prediction during design evaluation are also presented.

4.1 Contractual manufacturing

Contractual manufacturing (CM) is a commitment where the customer has designed the product and hands over the information to use in its manufacturing. This business commitment is sometimes referred to as make-to-print and the customer owns the product after it is manufactured. Two types of contracts were mentioned – *long-term agreement* (LTA) and *revenue and risk sharing partner* (RSP). While LTA is limited in time, e.g. five years, RSP is not. It is also possible to cancel LTA if the customer makes an RSP deal instead with another contractual manufacturer. RSP is seldom cancelled if the company does not declare bankruptcy or due to other force majeure situations.

Because of a found manufacturability problem or optimisation opportunity, the possibilities for redesign are small but possible. Tolerances can be changed as well as occasional design solutions, which is easier if a company representative is present. Sometimes, the manufacturing process is certified and then harder to change. One interviewee claimed that almost identical work processes are used for CM as for the transaction of physical artefacts:*"…one goes directly to the manufacturing preparation phases and for them nothing is essentially different."*

4.2 Transaction of physical artefacts

Transaction of physical artefacts (TPA) also involves, besides manufacturing, development of the design for the ownership of the customer. This is perhaps the most classical commitment of manufacturers, though this research focuses on business-to-business situations when the explicit functional requirements of customers need to be satisfied. Since the manufacturer also does design, there are greater opportunities to change the design to better suit the manufacturing environment.

4.3 Toward higher responsibilities

A greater responsibility mentioned is when the company, besides TPA, will also assemble the product with other components into a module. This commitment involves more logistics, purchasing, testing and balancing. Documentation and quality issues also increase at this level of responsibility. When the components arrive, it is possible to verify the tolerances from production before the customer receives the product.

Other responsibilities are when the company develops and supplies a whole engine for military purposes. These are long projects where comprehensive optimisation of the components is focused upon for manufacturability and maintainability. The company also mentioned the function focused business commitment of "function by the hour". This hardware may not be developed specifically to fit into a total offer, but rather the old TPA hardware is transformed into a functional sales or a PSS.

4.4 Manufacturability prediction issues during design evaluation

Predicting manufacturability raised certain concerns during the interviews. One issue is the risk for miscalculating the operation time, which can be costly if found after the price has been agreed upon with the customer. Another concern is predicting the volume of each motor program, especially for CM, as increases in material orders need to be completed up to one year in advance. There is also the issue of predicting life-cycle related issues to motivate the customer to initially pay more for the product. For instance, it may be beneficial to initially pay more for a more flexible product with a higher manufacturing cost that can easily be maintained later, rather than pay less initially and pay more later on due to maintenance problems, thus resulting in a higher total price than the first scenario. There is also an issue of how design and manufacturability evaluation can be integrated together with the prediction of possible contractors to avoid designs that are manufacturable in-house, but not possible for the contractors to supply, e.g. thickness of material is not possible to cast for the contractor. Lastly more simulation support is asked for: *"We want to simulate what happens when we put in a new product in the workshop!"*

5 Discussion

A higher level of design influence for the manufacturer at higher commitments may seem obvious, though the interesting question is finding the process parameters that are and are not affected. Miscalculation of manufacturing time for in-house manufacturing is likely to be unaffected, if the operation is unchanged. However, if a functional product demands a new hardware design, miscalculations are possible if proper simulations tools using, for example, computer aided manufacturing or rule-based design support such as knowledge-based engineering are not developed.

It is also possible that certain parameters are the same for some commitments and different for others. For example, one interviewee claims that the same process for manufacturing preparation was used for CM and TPA but it is argued by (Ericson, 2006) that there is probably a change in design process when approaching FPD. Also, when responsible for a module, a different responsibility is gained, but it is unclear if manufacturability evaluation is affected.

Because FPD involves developing hardware for a service, new issues arise during product development, e.g. integration issues. Therefore, it is reasonable to assume that manufacturability evaluation needs to be more integrated with the rest of development, such as design and contractor development. Integration with contractors is very evident if the contractor also sells a function rather than hardware. Computer tools incorporating a wider picture of the development process and assessing the maturity of the product knowledge might also be needed (Ericson et al., 2007). If a contractor is part of the extended enterprise and strives for win-win solutions the issues of handling increases in material may be less problematic, since the contractor can then guarantee availability.

Predicting the capacity needed during FPD is also more critical as wrong decisions might result in unnecessary costs because the company needs to ensure availability for the customer. Simulation is once again found essential in making the right decisions.

The life cycle issue mentioned might be less problematic if the company owns the product because they do not have to convince the customer to choose the more flexible product to maintain long-term customer satisfaction.

6 Conclusion

This paper presents a study done at a Swedish jet engine manufacturer to initially investigate the hypothesis "*manufacturability evaluation depends on the business commitment*". Pros for the hypothesis are firstly that functional product development is argued to need higher integration during product development. Secondly, higher level of influence at transaction of physical artefacts places higher demands on evaluation of manufacturability, since there is a possibility to optimise designs for production. Lastly, availability of contractor supplies to manufacturing processes could be overcome if the contractors offer their supplies as a function. Cons for the hypothesis are that same process definition for make-to-print as for transaction of physical artefact was used and for the module commitment, responsibility is not evident to affect manufacturability evaluation. In conclusion, some parameters of manufacturability evaluation are likely to be dependent on the business commitment, whereas others are not. There is therefore a need to continue the investigation and clarify the relationship between business commitment and manufacturability evaluation.

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