Early production involvement in new product development

Carin Rösiö (carin.rosio@jth.jh.se)
Mälardalen University/ Jönköping University

Jessica Bruch
Mälardalen University

Anette Johansson
Jönköping University

Abstract
In early phases of production system design important decisions are made that set prerequisites for the whole project. However, production engineers often gets involved when the decisions already are made. This paper aims to develop support for early production involvement founded on multiple case studies.

Keywords: Production system development, Decision making heuristics, Manufacturing industry

Introduction
The production system design process greatly affects new product development (NPD) performance, which has contributed to improved knowledge about designing production systems in a systematic way based on a predefined structure (e.g. Wu 1994, Ruffini 1999, Kulak et al. 2005, Bennett and Forrester 1993, Bellgran 1998, Blanchard and Fabrycky 1998). However there is still no consensus on what approaches to use in industry and the support for how to gather information and make decisions in production system design is limited.

Prior research offers insights and evidence that the capability of managing information is challenging and all but trouble-free. For example, literature frequently stresses the paradoxical situation that, although there is an abundance of information available, it is extremely difficult for the people involved to obtain necessary and relevant information when such is needed (Edmunds and Morris 2000). If too much information is provided, the person receiving information cannot use it effectively since he/she is burdened with a large supply of unsolicited information, some of which may be relevant (Butcher 1998). This is what Fodor (1987) refers to as environmental isotropy, i.e. in decisions and activities it is not always clear from the start which pieces of information are worth paying attention to and not. Isotropy is thus a violation of one of the major underlying assumptions of rational decision making behavior, and include one of the
factors that bound humans to act rational (Simon 1997). Information management thus takes up significant amount of time in a design process.

Searching for and accessing information can take up to 34 per cent of engineers’ working time (MacGregor et al. 2001). To fully use the potential of information as a basis for decisions, manufacturing companies need to have the capability to manage information in an effective way. In fact, it has been argued that the managing of information “plays a pivotal role in determining the success or failure” of new products (Ottum and Moore 1997, p258). The effectiveness of information management needs to be based on the capability to avoid situations in which the production system design process is either being subjected to information overload or getting information too late or not at all. Hence, capabilities are needed to deploy, integrate, and protect the information resource. Thus capabilities cannot easily be bought; instead they must be built within the organization (Teece et al. 1997, Frishammar 2005). Frishammar (2005) argues that the management of information is a capability that may allow for effective and efficient new product development and subsequently contribute to competitive advantages.

The inability to handle information and to make well founded decisions may have severe consequences including delayed launch to market, exceeding the budget, corrections in operation, customer dissatisfaction, reduced market share, and the impossibility of accomplishing development projects (Frishammar 2005, Baxter 1995). It has also been argued that an effective management of information contributes to the innovation capability of the manufacturing companies (Frishammar and Hörte 2005). The reasoning above highlights the critical role of information and its management for the success of the design process. Consequently, there is a need for empirical studies focusing on the management of information when designing production systems (Bruch 2012).

Managing of information could be divided into the dimensions of acquiring, sharing, and using information (Bruch 2012, Frishammar 2005, Ottum and Moore 1997). This paper focuses on the decisions making based on acquired information. The objective with this paper is to explore how decisions are made based on acquired design information in early phases of production system design in theory and practice. The purpose will be accomplished by a literature review and eight case studies where decision making when designing the production system has been studied.

Frame of reference

To design a production system implies generating, evaluating, and proposing a production system (Bellgran 1998). Design activities are usually carried out in a process describing the procedures that designers should follow. Having a process perspective supports the coordination of the work (Keen and Knapp 1996). Thus the production system design process is understood as a tool needed to manage and support the development activities. Since the process of designing a production system is very complex and needs to involve various functions and departments, the advantages of having a formalized process when developing a production system have been pointed out (Bruch and Bellgran 2013). In a production system design process the problem is normally defined in an initial stage where the project is initiated and defined in terms of, for example, project leader, budget, and time plan. Thereafter, an analysis of the background with present as well as future production systems and products including market research and environmental requirements is made. Based on this, objectives for the production system are formulated. The detailed design subsequently includes first designing conceptual production system
alternatives. The alternatives are thereafter evaluated in order to choose one final solution. The production system chosen is finally designed in detail (Wu 1994, Bellgran and Säfsten 2010).

A design process should clarify what should be done and when, what techniques and tools would be needed at each stage, what design information needs to be collected, and what the output of each stage would be (Love 1996). A design process should include both prescriptive and explanatory elements. While the prescriptive elements assist practitioners in carrying out activities in a certain way (what should be done, how it should be done and why it should be done), the explanatory elements refer to how things are perceived (McIvor 2000). McIvor (2000) also points out that a design process useful for practitioners should consist of a number of logically sequential steps that support a structured work approach to the decision making process. Also important features of an ideal production system design process described by Houshmand and Jamshidnezhad (2006) could be argued, i.e., to be simple enough to be widely used by engineers, efficient with a minimum of trial-and-error actions, and versatile enough to be applicable in different situations.

The support for decision making in production system design literature and the proposed design processes are largely characterized by the thoughts of rational decision making. The normative, rational process of decision making can be described as: recognizing a problem, collecting information, generating and evaluating alternatives, and selecting the most satisficing alternative (Simon 1965). This sequence of decision making is referred to as the identification, development and selection model by Simon (1965), sometimes referred to as the synoptic, or comprehensive model of decision making (Eisenhardt 1989b). This model is based on the general assumption that humans are utility-maximizing beings.

The production system design process thus advocates a comprehensive collection of information on which formal decisions should be made. However, the information in the production system design process depends on the particular context and whether it enables necessary activities and decisions to take place (Galliers 1987). Organizations also have a natural tendency to create a terminology and system of meaning of their own (Weick 1969). Finally, most of the information required in the production system design process can only be found in the minds of experienced system designers (Bellgran 1998). Thus, information is often unique and deeply embedded in the organization, by which it satisfies the demand to be scarce and difficult to imitate and substitute (Lewis et al. 2010).

From the 1970s and onwards, research on decision making within the management field has turned away from dealing with normative decision making processes to emphasize more descriptive, heuristic processes developed within the framework of cognitive psychology and information processing (Sarasvathy 2001, Simon 1997, Kahneman and Tversky 1974, Ranyard et al. 1997). While these more recent models of decision making are generally accepted, the notion of rationality forms a starting point for much decision making theory, primarily in the normative and prescriptive research aiming at finding best practices, including the literature on production system design (e.g. Love 1996). Thereby the rational decision making models heavily influence the way managers try to optimize decision making behavior in their organizations in a way which is counter intuitive to more contemporary research findings based on descriptive empirical research, such as the meaning of intuition in decision making (Simon 1987, Woiceshyn 2009), the use of heuristics as cognitive shortcuts (Einhorn 1982, Kahneman and Tversky 1974) and different approaches to decision making depending on the context (Wiltbank et al. 2009,
These contextual factors are discussed by Simon (1987) as the premises of the decisions which are entered into a decision making process involving “fact-finding, design, analysis, reasoning, negotiation, all seasoned with large quantities of “intuition” and even “guessing” (Simon 1997, p. 24). Research in the field of entrepreneurship, exploring how experienced entrepreneurs make decisions when facing uncertain futures offers an alternative take on how decision making can be approached (Sarasvathy 2001). This set of decision making heuristics, or logics is called effectuation, and based on the knowledge about how expert entrepreneurs go about creating new businesses and markets, it offers an alternative approach to uncertainty by arguing that prediction and control do not necessarily go hand in hand. In doing so effectuation is positioned as a control-oriented, transformative approach based on a non-predictive strategy (Wiltbank et al. 2006) and challenges the traditional focus on prediction in decision making with an underlying logic suggesting that to the extent we can instead control the future “we do not need to predict it” (Sarasvathy 2001, p. 251). The decision making heuristics embodies four core principles: a) Affordable loss meaning that rather than setting goals of return on investments entrepreneurs decide what they can afford to lose; b) Openness to building strategic alliances by inviting self-selected stakeholders to pre-commit to co-create the project as a way of reducing uncertainty; c) Exploiting contingencies meaning embracing unexpected events and using them to reshape the outcome, and finally d) Controlling an unpredictable future through action - as opposed to trying to predict it - through Experimentation with different solutions (Sarasvathy 2001). These logics are conceptual opposites of the normative, rational decision making process – however in practice both logics are used depending on the level of uncertainty. In this paper, we analyze the existing decision making in early production system design processes in eight case studies, and theories of rational and effectual decision making to evaluate its occurrence and potential to overcome the gap between systematic decision making protocols and the uncertainty pertaining to information access and evaluation often involved in design processes.

Methodology

Data were collected by case study methodology (Yin 2009) where each case represented a production system design projects. The cases were selected for theoretical reasons (Eisenhardt 1989) with the goal to make it possible to extend the emergent theory. The cases had a holistic design (Yin 2009) in which the decisions making when designing the production system were studied in the project. This includes both the available support for decision making and how the decisions were made. Eight production system design projects were studied in four real-time case studies and four retrospective case studies in totally five companies. To enhance validity, real-time studies were combined with retrospective studies (Leonard-Barton 1990). Through real-time studies, post-rationalization was avoided, thus increasing internal validity. Furthermore, retrospective studies gave a more controlled case selection and thus increased external validity (Voss et al. 2002). Data were gathered by semi-structured interviews, observations, and document studies (Yin 2009), see Table 1. All cases have been carried out at global manufacturing companies except one (case study B), which was performed at a medium-sized manufacturing company.

Before an interview started, the terminology used was presented to the respondents in order to avoid misunderstandings. All interviews were recorded and transcribed. The
The next step in the case studies involved an analysis of relevant documentation such as project models, production system design models, production system design support, support for requirements specifications, and checklists and support used by individuals, all of which were made fully available. In two of the cases, observations were made that implied attendance at project meetings in the project. In all cases an ongoing dialogue was held with key persons involved until rich descriptions of the single cases were achieved (Yin 2009).

The case studies were conducted by two researchers, of which one conducted case studies A, B, D, E, F and H, while the other researcher conducted case study C and G. Continuous contact was maintained between the researchers. Due to the combination of real-time and retrospective studies, the role of the researchers varied between the case studies. In case study A the researcher was present at the site approximately five days a month as long as the case lasted. In case B the researcher was present every week during the case. The retrospective studies involved already closed production system design projects, and consequently a different approach was required. Apart from the visits required to carry out the initial interviews, regular contact through email and telephone was maintained with key persons in the production system design teams.

<table>
<thead>
<tr>
<th>Case study</th>
<th>Data collection techniques</th>
<th>No. of interviews (single/group)</th>
<th>Duration</th>
<th>Respondents</th>
<th>Company description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case A Retropective</td>
<td>Documentation Interviews</td>
<td>10 (10/0) 32-63 min</td>
<td></td>
<td>Production Engineering Manager, Production Manager, Operative Buyer, Assembly Operator, Production Planner, Product Engineer, Production Engineer, Logistics Engineer, Project Leader,</td>
<td>Sweden OEM</td>
</tr>
<tr>
<td>Case B Real-time</td>
<td>Observations Documentation</td>
<td>-</td>
<td></td>
<td>-</td>
<td>Sweden First-tier supplier</td>
</tr>
<tr>
<td>Case C Real-time</td>
<td>Observations Documentation Interviews</td>
<td>Face-to-face 10 (10/0) 40-90 min</td>
<td></td>
<td>Production Engineering Manager, Industrialization Project Manager, Advanced Engineering Project Manager, Program Manager, Operations Manager, Quality Assurance Engineer, Logistics Manager, Vice President, Production Manager, Production Engineer, Workshop Manager</td>
<td>Sweden First-tier supplier</td>
</tr>
<tr>
<td>Case D Retrospective</td>
<td>Documentation Interviews</td>
<td>Face-to-face 2 (1/1)</td>
<td></td>
<td>Industrialization Project Manager, Senior Industrialization project</td>
<td>Sweden OEM</td>
</tr>
</tbody>
</table>
The analysis of data included data reduction, data displays, and conclusion drawing and verification (Miles and Huberman 1994). Relevant data, both from internal documentation, observations, and the interviews were gathered and structured in tables. The analysis process was iterative and of an explorative nature. Within-case analysis was complemented with cross-case analysis to provide possibilities of pattern matching (Yin 2009).

**Analysis and Results**

In all cases a project model of a stage-gate character was used and most of the respondents also ensured that this project model was followed. The principles of the production system design processes described in the literature are based on rational decision making (Simon 1965) where problems are identified, information collected, alternatives proposed and solutions are generated. The project models were initially designed for product development and that was also by whom it still primarily was used. Production system design activities and decision points were added to different extent to
the project models. In the project models in case C and D the models gave a limited support for the actual production system design, e.g. specifying what to do in the different phases, who is responsible and what information that need to be collected before decisions should be made. In the other cases this information was scarce. None of the documented processes or project models described in detail a complete picture of what information was needed in the different stages. In addition, support for designing production systems in terms of checklists and templates for requirement specifications were used. However, in none of the case studies a structured production system design process (as defined by e.g. Love (1996)) was fully developed. A rational decision making process in line with theoretical production system design processes (Wu 1994, Bellgran and Säfsten 2010) were on one hand advocated in order to fit the existing project model used for NPD. On the other hand, the prerequisites for the production engineers or industrializations engineers to be able to follow such a process were considered to be poor due to e.g. time pressure, the level of complexity in the task and competence available. Therefore, effectuation was an occurring decision heuristic. Most of the respondents in all case studied describe an unwillingness to have a very detailed structured process requiring formal decision points. According to the respondents the design of production system is complex and a too structured process would delimit their flexibility.

Several of the cases showed a lack of in-house competence in design of production systems, i.e. there were only a few production engineers or industrial engineers that could work with the design of the production system. In case study H only one person was assigned for production system design and in case study F there were two. To strengthen production system competence, external production system suppliers were used.

Decisions were made differently depending on type of decision and position in the design process in the case studies. In all cases informal decisions were made by the responsible person for the production system design combined with major decisions that were made during gate meetings. However, no clear tendency could be identified in this study of when and why certain decisions were made.

A result from all cases is that the design information on which the decisions were based seldom was documented in a formal way but kept in the production engineers mind. In the case study H the design of the production system was performed in discussion with the system supplier and very few requirements were documented. Even if the stage-gate model was followed carefully, it gave limited support for designing production systems, as previously mentioned. Similarly, in case study B production systems were mainly designed based on the staff’s existing skills. This is in line with previous research pointing out that production system design is founded on past experience and judgement based on experience (Yien 1998).

**Discussion and conclusion**

Researchers within the manufacturing area have during decades pointed out a need for structured design processes (Bennett and Forrester 1993, Wu 2001, Bellgran and Säfsten 2010) however, with limited success. According to previous research studies (Duda, 2000, Chryssolouris 2006), the design of production systems in practice often evolves ad hoc and is not based on a long-term plan, which was also shown in these case studies. A structured design process is in industry advocated to a certain limit but the flexibility and the decision space may not be delimited. What is important for superior production system design is how it supports manufacturing companies in their attempts to achieve faster time to market, smoother production ramp-up, enhanced customer acceptance of new products, and/or a stronger proprietary position (Pisano 1997, Hayes et al. 2005). This does not necessarily
means a formal and structured process. It is not for sure that this means an exclusion of ad-hoc decisions as Houshmand and Jamshidnezhad (2006) argue.

The analysis of the eight case studies shows a willingness to develop structured production system design processes supporting a rational decision making. However the present situation often requires that decision to some extent are based on “intuition” and “guessing” (Simon 1997, p. 24) based on the production engineers previous experience and knowledge. Effectuation in production system design is seldom advocated neither in theory nor in practice. However, the case studies show that this is an occurring decision heuristic. A conclusion made from this study is that existing theoretical production system design processes gives limited support for production system design in industry today. In addition, there is limited research on how to handle information in different stages and how to make decisions based on information in different stages.

Based on this paper the following proposition are made.

(a) Different decision heuristics could be used in different stages of the production system design process.

(b) The production system design models that exist in literature need to be more pragmatic in the sense that effectuation could be advocated for decisions in specific phases and activities.

These propositions will be treated in future research.

References


