Greening Our Global Manufacturing Enterprise

Daniel Fitzgerald
The A. James Clark School of Engineering
University of Maryland – College Park
Phone: 410-919-3914
Email: dfitzy@mail.umd.edu

Advised by:
Dr. Jeffrey W. Herrmann
The A. James Clark School of Engineering
The Institute for Systems Research
University of Maryland – College Park
Phone: 301-405-5433
E-mail: jwh2@eng.umd.edu

Dr. Linda Schmidt
The A. James Clark School of Engineering
The Institute for Systems Research
University of Maryland – College Park
Phone: 301-405-0417
E-mail: lschmidt@eng.umd.edu

Greening Our Global Manufacturing Enterprise

Abstract

This report presents a perspective for addressing one of our enterprises main future issues, the Environment. The decision production system perspective represents a product development organization as a network of decision-makers and information processors through which information flows. This representation can be used to improve product development processes by providing a deeper understanding of information flows and key decisions.

Note: I approached this report by considering myself as an environmental consultant to the enterprise. I understand there are many other issues facing global manufacturing enterprises in the year 2025 but I felt presenting the perspective with respect to one major issue would be clearer to the reader. The perspective can be applied to other issues as well.

1. Introduction

Today, we are currently facing pressures to become a more environmentally responsible manufacturing enterprise. Issues such as "the fossil fuel supply, global warming, depletion of the o-zone layer, misdistribution of water use, and the loss of forest have been described by some as 'extinction-level' crises" [1]. Up to this point, environmental issues within manufacturing firms have been monitored using typical "manufacturing" metrics such as air emissions metrics, water emission metrics, and total land-filled waste. Consequently, much of the work to improve these end-of-line metrics are "patch jobs" such as adding filters to smokestacks. Instead, we should be designing products whose manufacturing processes naturally reduce air emissions. As responsible members of society, we must incorporate the idea of sustainability into our engineering and manufacturing processes. We must understand that the greatest opportunity for Environmentally Responsible Product Development occurs during the product design phases, specifically the early design phases [2-5].

So far, manufacturing firms have had trouble incorporating the assessment of environmental issues into the design process. One reason for this is often times companies purchase a standalone Design for Environment (DfE) tool and try to "force" it into their product development process. Design engineers are told to use the tool to assess a product's environmental performance. The result is usually a post-design assessment of the product's performance on a number of environmental objectives that may have little relevance to the firm. Consequently, environmental performance is not evaluated during the design process, and changes cannot be made to improve environmental performance.

To overcome the limitations of standalone DfE tools, our manufacturing enterprise needs to consider important environmental objectives in a systematic way during the design process. In order to improve a product development organization, an understanding of the information flows and decision-making is necessary. Busby [14] has identified common failures that occur during decision making in product development:

- Not involving others in decisions (which limits the information used to make the decisions);
- Not telling others the assumptions that they can make, the normal requirements, and the exceptional circumstances that can occur;
- Not considering other's goals or requirements;
- Not knowing the effect of one's action on another, not knowing the effect of a change on another;
- Not defining the scope of tasks allocated to others, and not determining the scope of tasks assigned to oneself.

Many of these errors stem from not understanding the information flow and decision-making in the product development organization and not seeing one's role in the decision production system. That is, they are failures to maintain information responsibility [15]. Simon [7] argues that systematic analysis of the decision-making in a product development process would be useful for implementing changes to the product development organization in a timely and profitable manner.

The decision production system perspective [6] is a unique way to view a product development organization. This perspective views product development organizations as a network of decision-makers, information processors, knowledge repositories (e.g, handbooks), and interactive databases (e.g., product data management systems) through which information flows. By viewing organizations in this manner, one can understand how information flows and who is making the key decisions. This representation allows for a deeper understanding of the organization than typical hierarchical charts or Gantt charts of product development projects. Understanding the real process (as opposed to the corporate guide for the design process) is a key step in improving product development. Furthermore, recognizing design as a "knowledge agent" and the designing activity as a crucial organizational knowledge process can improve an organization's ability to innovate within their competitive environment [16]. The need for research on new work practices [17] and the need for developing new representation schemes for product

development [18] are additional motivations for the decision production systems perspective.

2. The Decision Production System

A decision production system [6] is defined as an information flow governed by decision-makers who make both design decisions and development decisions under time and budget constraints. Since decision-making requires information, generates information, and determines who gets what information, employees on different hierarchical levels will be exchanging information at different points in the product development process. Yet all are involved in the processing of information and knowledge at the same level. In this way they resemble operators on the same shop floor.

The decision production system (DPS) perspective looks at the organization in which the product development process exists and considers the decision-makers and their information processing tools (like databases) as units of a manufacturing system that can be viewed separately from the organization structure. As a result the hierarchical view (Figure 1) and decision production system view (Figure 2) of a product development organization are quite different. This was observed by Simon [7], who notes that an organization's "anatomy" for information processing and decision-making is naturally different than the departmentalization displayed in an organization chart. The greater the interdependence between decision-makers, the less the DPS will resemble an organization chart.

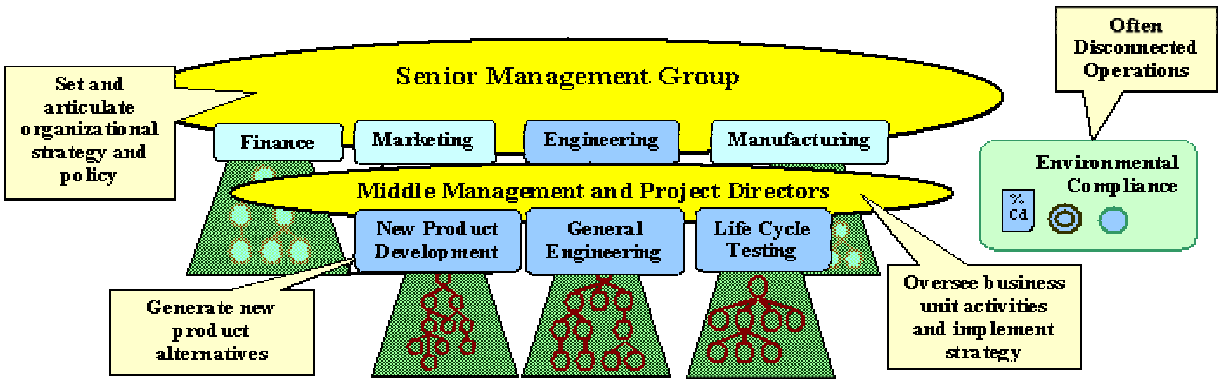

Figure 1 – Hierarchical Chart

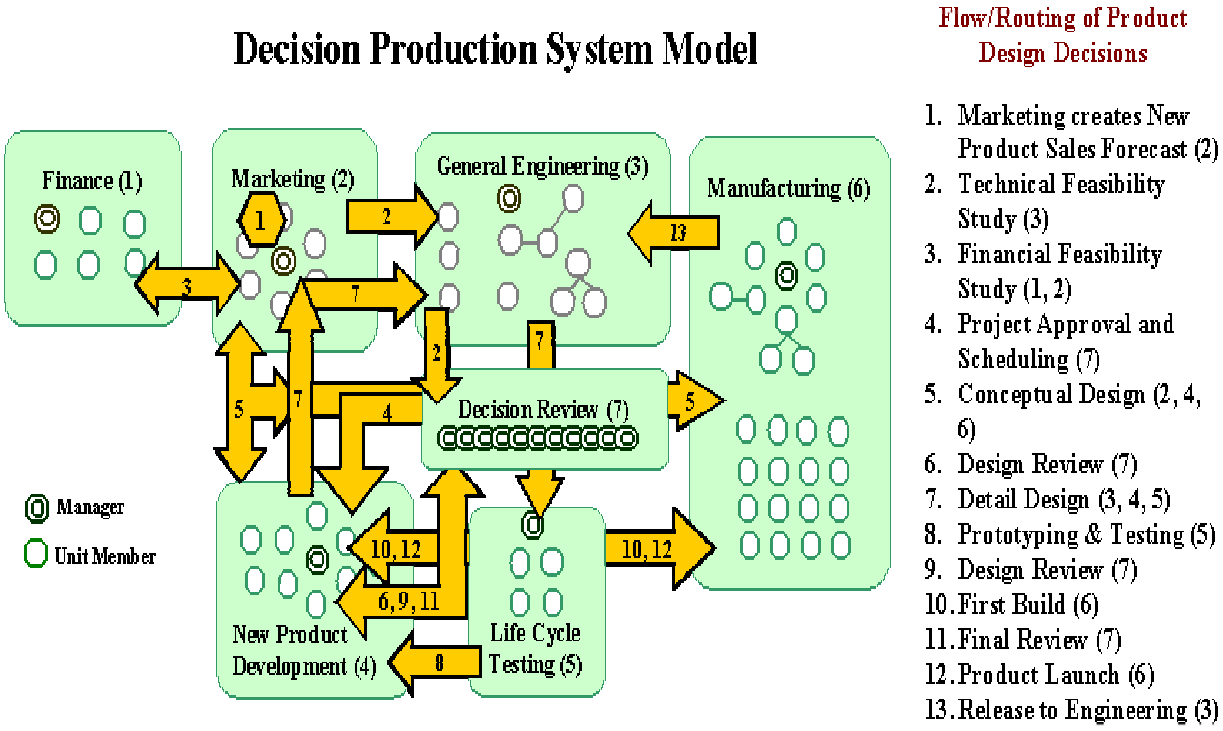

Figure 2 – Decision Production System

There are similarities between a decision production system and a factory [6, 7]. With a factory, parts flow from one machine to another. This view is analogous to product development organizations since information flows from one decision-maker to another (or between information processors who transform data for decision-makers). But the simulation of a decision production system is much more difficult due to the iterative nature of a product development process, the preemption that occurs as engineers interrupt one task to work on another, the difficulties in identifying sources of knowledge within the organization [7] and outside the organization, and the difficulty of defining the scope of a design task. (There have been some initial attempts to gain managerial insight from theoretical models based on the decision production system perspective [8, 9].)

However, the decision production system perspective emphasizes the roles that individuals play and the information flow between them. This non-traditional focus

allows what Simon calls a “fresh” look at organizations [7]. Research shows that knowledge transfer is facilitated when participants in any process know where to look for information inputs [10]. In addition, knowledge retention and transfer increase when the properties of the units using the knowledge “fit” or are “congruent” [10]. The decision-production system can be used to identify existing flows of information that can be exploited by their fit to a new set of knowledge learning activities. “Piggybacking” or “overlapping” or “overlaying” new information flows onto existing flows of similar or relevant information provides an opportunity to enhance organizational learning. This is especially true when a knowledge repository exists that can be expanded to accommodate a new set of transactions that will enrich its holdings.

Thus, a useful representation for an organization’s decision production system is a swimlanes chart [11, 12]. A swimlanes chart is “a special type of flowchart that adds more detail about who does which activities” [11]. The people that are responsible for activities are listed on the left-hand side of the chart vertically and are separated by lines (swimlanes). Tasks are then listed from left to right, usually in time sequential order, and are connected with arrows to demonstrate information flow. Figures 3 is an example of a swimlanes chart.

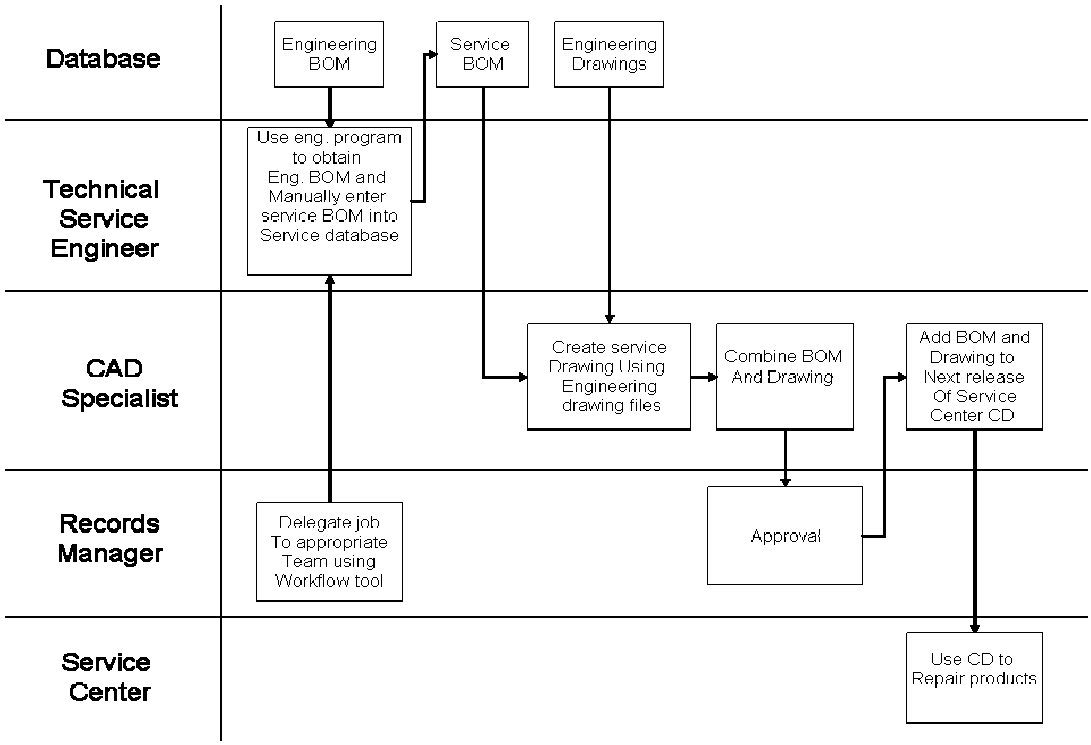

Figure 3 – Swimlanes chart

3. Applying Decision Product Systems to a Global Manufacturing Enterprise

Within a global manufacturing enterprise, there is usually a predefined process in place that defines the tasks of the functional units from concept generation to the launch of the completed product. The process is set up in a timeline manner where tasks that occur in the beginning of the process must be completed before the project can move forward to the next set of tasks. There are usually gates that require managerial approval before a project can move forward to the next stage. All of these tasks and signoffs are formally documented to define the organization's product development process.

When individuals outside of the product development process read the documented product development process, they may feel that they have sufficient knowledge of how the organization is run. But when they become part of the organization and are involved with the tasks of the process, it becomes apparent that what actually happens is much different. First, significantly more information flows between functional units than that which is documented. Second, decisions are made not only at key points in the process but within the tasks themselves. Typical organizational representations such as flowcharts

of the product development process and organizational hierarchies showing superior-subordinate relationships do not (and cannot) sufficiently describe information flow and decision-making. If changes are to be made to the product development process, it is first necessary to understand what is actually happening in the process. A decision production system representation of the whole product development process or a critical subset shows information flows and the people involved (the decision-makers).

Consider, as an analogy, the system of sidewalks on a university campus. The paved paths that are laid out on the ground are the predetermined paths where students are supposed to travel to reach their classes. At first, one believes that all students follow the sidewalk paths until they reach their destination. Upon further inspection however, one will notice that there are pathways of dead grass that the students are using. Each is an additional actual path that the students are using because they have found it more convenient than the established paths. The university officials must then decide if this pathway of travel is appropriate. If so, then they will construct a sidewalk to reinforce the use of the pathway. If not, they will find a way (such as a fence) to divert the students from the pathway. With sufficient knowledge of students' actual walking process, it is possible to make effective changes to the process.

To improve our global manufacturing enterprise, we will use the four step process that is illustrated in Figure 3. The first step is to study a particular set of activities within a product development organization in detail, which in our case is environmental issues. This leads to the construction of a model based on the DPS perspective. There are many possible types of models, from flowcharts to value stream maps to discrete-event simulation. Visual models, like networks, are good because they support perceptual inferences [13]. I have found swimlanes to be particularly useful. Analysis of the model leads to the identification of desirable changes. Representatives from our enterprise can help determine which are the most feasible. Finally, we must implement the changes. Follow-up activities are needed to document the new procedures, to train individuals, to ensure that the new procedures are followed, and to determine the benefits and limitations of the change, which leads to further study in a cycle of continuous improvement.

Figure 3 – Product Development Organization Improvement Process

4. Systems Approaches

There are two main categories of systems approaches when discussing systems that involve people: Functionalist Approaches and Interpretive Approaches. A functionalist approach views a manufacturing enterprise as a machine, an organism, a brain, or a transformation and is useful where there is a shared and clearly identifiable goal. Examples of situations where functionalist approaches are used are production planning and military logistics questions. Common techniques used in functionalist approaches are mathematical modeling and optimization.

An interpretive approach is appropriate when a problem has no single clearly identifiable goal or when there is no objective way to view a system. These types of approaches take into account to different people have different perspectives of a system depending on their role in the system. When researching a problem that requires an interpretive approach, it is necessary to interview multiple people to develop a shared vision that every participant can accept. Typical interpretive approaches include soft systems methodology, interactive management, and interactive planning.

The decision production system perspective is an interpretive approach to systems engineering. Going back to the four step process in Section 3, many people are

interviewed during the study product development organization phase. Then, after the DPS model is created, the model is analyzed by all participants to ensure that the process is accurately represented. Throughout the iterative stages of the product development improvement process, all participants are required to "buy-in" to each stage or else the changes may not be fully implemented.

5. Concluding Remarks

This paper demonstrates the applicability of the decision production systems perspective to help us become an environmentally responsible manufacturing enterprise. Time, effort and iteration are necessary to get the information needed to create a representation that accurately models a decision process. Appropriate time needs to be devoted to developing accurate process representations or the perspective will not be helpful. As the old saying goes, "Garbage in, garbage out." While this report dealt with the issue of the environment, the decision production system perspective can be applied to any product development organization or activity. This versatility combined with the level of understanding it provides combine to be an innovative tool for creating effective processes.

The assessment of this approach remains for future work. Such an assessment may need to involve performance metrics such as: the time required for DfE reviews, the number of additional tasks required, the improvement in product environmental metrics, and the percentage of questions that can be accurately answered in customer questionnaires. Papers dealing with validating a design method have been reviewed [20,21] and will be useful in the validation process. Further research using this methodology will establish its usefulness for improving product development.

6. Acknowledgements

I would like to thank my advisors, Dr. Jeffrey W. Herrmann and Dr. Linda Schmidt for their support and encouragement, the National Science Foundation under grant DMI-0225863 for funding this project, and the Achievement Rewards for College Scientist (ARCS) Foundation for supporting my research.

References

[1] National Academy of Engineering, "The Engineer of 2020" The National Academies Press, Washington D.C., 2004.

[2] Handfield, Robert B., Steven A. Melnyk, Roger J. Calantone, and Sime Curkovic, "Integrating environmental concerns into the design process: the gap between theory and practice," *IEEE Transactions on Engineering Management*, Volume 48, Number 2, pages 189-208, 2001.

[3] Fiksel, Joseph. *Design for Environment: Creating Eco-efficient Products and Processes*. McGraw-Hill, New York. 1996.

[4] Bras, Bert. "Incorporating Environmental Issues in Product Design and Realization," *UNEP Industry and Environment* (January–June) 20(1–2), 5–13. 1997.

[5] Ashley, Steve. "Designing for the Environment," *Mechanical Engineering*, Vol. 115, No. 3, pp.53-55. 1993.

[6] Herrmann, Jeffrey W., and Linda C. Schmidt, "Viewing product development as a decision production system," DETC2002/DTM-34030, Proceedings of the ASME 2002 Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Montreal, Canada, September 29 - October 2, 2002.

[7] Simon, Herbert A., *Administrative Behavior: A study of decision-making processes in administrative organizations,* 4th ed, The Free Press, New York, 1997.

[8] Herrmann, Jeffrey W., "Controlling iteration in product development processes," working paper, June 15, 2004.

[9] Zhu, Jian, Ali A. Yassine, and Ramavarapu S. Sreenivas, "Information incorporation policies in product development," DETC2004-57351, Proceedings of the ASME 2004 Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Salt Lake City, Utah, September 28-October 2, 2004.

[10] Argote, Linda, McEvily, Bill and Ray Regans, "Managing Knowledge in Organizations: An Integrative Framework and Review of Emerging Themes," *Management Science*, Vol. 49, No. 4, April 2003, pp. 571-582.

[11] Herrmann, Jeffrey W., "Information flow and decision-making in production scheduling," Proceedings of the 2004 Industrial Engineering Research Conference, Houston, Texas, May 15-19, 2004.

[12] Sharp, Alec, and Patrick McDermott, *Workflow Modeling*, Artech House, Boston, 2001.

[13] Simon, Herbert A., and Jill H. Larkin, "Why a Diagram is (Sometimes) Worth 10,000 Words," in *Models of Thought,* Volume 2, Herbert A. Simon editor, Yale University Press, New Haven, 1989.

[14] Busby, J.S., "Error and distributed cognition in design," *Design Studies*, Volume 22, pages 233-254, 2001.

[15] Drucker, Peter F., "The coming of the new organization," in *Harvard Business Review on Knowledge Management*, Harvard Business School Press, Boston, 1998.

[16] Bertola, P., and J. C. Teixeira, "Design as a knowledge agent: How design as a knowledge process is embedded into organizations to foster innovation", *Design Studies*, **24**(2003): 181-194.

[17] Brown, John Seely, "Research that reinvents the corporation", in *Harvard Business Review on Knowledge Management*, Harvard Business School Press, Boston.

[18] Krishnan, V. and Karl T. Ulrich, "Product development decisions: a review of recent literature," *Management Science*, Vol. 47, No. 1, pages 1-21, 2001.

[19] Herrmann, Jeffrey W. "A Brief Overview of Systems Approaches", Class Notes, March 24, 2003.

[20] Seepersad, Carolyn C., Kjartan Pedersen, Jan Emblemsvag, Reid Bailey, Janet Allen and Farrokh Mistree, "The Validation Square: How does one verify and validate a design method?" Draft.

[21] Olewnik, A.T., Lewis, K.E., On Validating Design Decision Methodologies, *Proceedings of the 2003 ASME Design Engineering Technical Conferences*, Chicago, IL., September 2-6, 2003.