Managing Iterations in Product Development Process Using Dependency Structure Matrix

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Abstract. The market is highly challenging with customers demanding a variety of products at competitive prices. To make a product competitive, it needs to be introduced quickly without compromising on its performance or quality. Thus, reduction of product development cycle time has become essential for companies to thrive and sustain in the market. Product Development (PD) is the set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product. Companies are forced to develop a well-coordinated development plan to organize their processes and resources to develop competitive products. Today PD confronts complex development challenges. The difficulties in developing complex engineering products do not only arise from their technical complexity but also from the managerial complexity necessary to coordinate the interactions between the different engineering disciplines, which impose additional challenges on the development process. Traditional Project Management techniques are limited in application. Researchers and design managers are constantly searching for the effective and efficient methods for managing PD process. To address the limitations of traditional project management tools, Design Structure Matrix (DSM) has been identified as a sensible tool to represent PD process. In this work, the capability of DSM is demonstrated with a real life case example. The necessity of reducing iterations in PD process using PSM 32 software is also demonstrated

Keywords: Product Development (PD), Design Structure Matrix (DSM), PERT, CPM.

1. Introduction

Product Development process is the sequence of steps or activities, which an enterprise employs to conceive, design and commercialize a product [1]. Many of these steps and activities are intellectual and organizational rather than physical. Some organizations define and follow a precise and detailed development process, while others may not even be able to describe their processes. There are various
categories of new products such as new to the world products, new category entries, addition to product
lines, product improvements and repositioning [2] Product development includes various types of
decisions made by engineers and managers. Some decisions are related to design while others are
development decisions [3].
Design Structure Matrix is a generic matrix-based framework for information flow analysis introduced by
Donald Steward in 1981. DSM consists of an N-Square diagram showing the interaction of each element
with every other element in the model. By reading across a row, one can observe these interactions
through the cell contents corresponding to each cross-referenced column. The use of DSMs in both
research and industrial practice increased greatly in 1990s.
A sample task based DSM is shown in Figure 1. Tasks appear identically labeled in rows and columns of
the matrix are arranged top-down according to their sequence of execution.

Three types of task interactions can be observed from the matrix, namely, independent, dependent and
coupled[4]. In Figure 3, Tasks 1 and 2 are “independent” since no information exchange is required
between them. These tasks can be executed simultaneously (parallel). Tasks 3–5 are engaged in a
sequential information transfer and are considered “dependent”. These tasks would typically be performed
in series (sequential). Tasks 6 and 7, however, are mutually dependent on information. These are
“interdependent” or “coupled” task blocks and are often requiring multiple iterations to complete. Marked cells above the diagonal represent iterations in the process. This occurs when an activity is dependent on information from a task scheduled for a later execution. Such scenarios often lead to rework and are undesirable. A number of algorithms have been developed to minimize such instances of iteration by re-arranging the sequence of tasks in the process. Partitioning and tearing are two main processes that can manipulate the matrix and transform the matrix into lower triangular form. It is the process of rearranging the order of activities by moving an entire row and column on either side in such a way that the resulting matrix has marks either below the diagonal or close to the diagonal. Through the manipulations, the task execution sequence will be reordered, the number of iterations will be reduced, and fewer tasks will be involved in the iteration cycle and these will result in a faster development process.

2. DSM Applications in PD

Engineering design often involves a very complex set of relationships among a large number of coupled problems. It is this complex coupling that leads to iteration among the various engineering tasks in a large project. Iterations are fundamental to the engineering design process. PERT chart often created by managers to depict PD describes the process as a progression of series and parallel activities; however coupled and iterative PD processes are in fact quite common (Kline,1985). DSM is useful in identifying where iteration is necessary. Understanding design iteration is therefore fundamental to accelerating and improving product development practices. There are two ways to accelerate an iterative development process:

1. To execute faster iterations
2. To conduct less iteration.

Both approaches are important to consider. Faster iterations are achieved through several means, such as the use of engineering models or information technology. Less iteration may be experienced when the coupled development activities can anticipate each other’s results, or when extraneous activities are removed from the iterative portion of the process. Models of design iteration can provide valuable insight into the iteration process. As iteration is common in most PD projects, especially in the product design stage, it will cause rework and require extra communication and negotiation that result in a prolonged development process. There are many approaches for handling these design iterations [5] [6] [7]. Iteration can be managed in many ways such as improving the sequence of design activities to streamline information flows which form the basis for task dependencies [8] developing new engineering automation tools to perform iterations faster [9] adding resources at bottleneck activities [10]. One way of managing rework effectively is to avoid interdependent tasks. There are many possible ways to avoid the coupling of interdependent tasks by splitting a task into two or more tasks, combining two or more tasks into a single task, redefining the project tasks and their relationship itself, or sometimes breaking the relationship between the tasks. In order to speed up this iterative design process, the DSM methodology suggests the manipulation of matrix elements such that iterative behavior could be removed from the matrix, or at least minimized. Partitioning and tearing are two main processes that can manipulate the matrix and transform it into lower triangular form. Through the manipulations, the tasks execution sequence will be re-ordered, the number of iterations will be reduced and fewer tasks will be involved in the iteration cycle and these will result in a faster development process.
Several researchers have developed models of design iteration. Ha and Porteus [11] present a model of coordination between two coupled development activities. They address the frequency of design reviews at which times information is transferred between the activities. The sequential iteration model allows computation of the total lead-time for a group of tasks where each task has a probability of creating rework for the other tasks[12]. Each of these modeling efforts is an important contribution in this new and emerging area of management science because each model is able to explore a different facet of design iteration. Unfortunately many PD managers fail to plan for iterations; consequently PD projects incur schedule and cost overruns [13]. Browning identified cycle time reduction challenges and highlighted the capabilities of DSM based methods to manage projects for reduced schedule risk and shorter cycle time[14]. Maheswari et al. applied DSM representation for activity sequencing in concurrent engineering projects [15]. Using this representation, information dependency attributes can be organized and analyzed in a structured manner to identify activity groups and sequence for concurrent execution. The procedure is applied to the design phase of an induced draft cooling tower project. Gohlich et al [16] proposed an augmented DSM sequencing to support product development planning.

3. Case Example

For the illustration of the advantage of the DSM, a PD process which consists of 27 activities is modeled. Process modeled using DSM in PSM32 software is shown in figure 3. In activity dependency matrix, Activity 1 and 6 is marked as 0 which means Activity 6 produces an output that is an input to Activity 1. All such relationships are documented in the activity dependency matrix. The matrix is subjected to partitioning to rearrange the tasks and eliminate as many feedback loops as possible. Final partitioned matrix is shown in Figure 4. The sequence 1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24-25-26-27 is rearranged and new sequence is obtained as 1-2-6-4-5-7-3-8-9-10-11-12-13-14-15-16-17-18-19-25-20-21-22-23-24-26-27.

Table.1 List of activities in product development process

| Sl No: | Activity                                      | Sl No: | Activity                                      |
|-------|-----------------------------------------------|-------|-----------------------------------------------|
| 1     | Idea Generation SWOT Analysis                 | 15    | Break Even Analysis                           |
| 2     | Idea Generation Brainstorming                 | 16    | Beta Production Run                           |
| 3     | Idea Screening Customer Analysis              | 17    | Internal Testing                              |
| 4     | Idea Screening Market Analysis                | 18    | Focus Group Interviews                        |
| 5     | Idea Screening Competitive Analysis           | 19    | Determine Necessary Adjustments               |
| 6     | Idea Screening Technical Feasibility          | 20    | Initial Production run for test Market        |
| 7     | Idea Screening Finalize Idea Selection        | 21    | Market Testing                                |
| 8     | Concept Development                           | 22    | New program Initiation                        |
| 9     | Feature Specification                         | 23    | Quality Management System                     |
| 10    | Rapid Prototyping                             | 24    | Operational Planning                          |
| 11    | Production Optimization Analysis              | 25    | Distributor Negotiation                       |
| 12    | Concept Testing                               | 26    | Market & Advertising Campaign                 |
| 13    | Pricing Analysis                              | 27    | Product Launch                                |
| 14    | Sales Forecast                                |       |                                               |
Figure 3. DSM Matrix showing dependency

Figure 4. DSM after partitioning using PSM 32
4. Conclusion

Managing and scheduling the complex product development projects is a difficult exercise that requires much skill and experience. The traditional project management tools are weak in the areas, such as sequencing, controlling and managing the product development projects. In this work, Design Structure Matrix is used to tackle the problems encountered in scheduling the complex and interrelated product development projects. The re-sequencing of tasks is done using PSM32 software.

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