Planning Business Processes in Product Development Organisations

David Wynn, Claudia Eckert and P John Clarkson

Department of Engineering, Trumpington Street, Cambridge CB2 1PZ, UK
{dcw24 | cme26 | pjc10}@cam.ac.uk

Abstract. Business processes are difficult to plan successfully, and become more so with increases in complexity. However, certain types of business process are known to be more difficult to plan than others. One example is the process of product design, as followed during the development of physical artefacts for production [2]. This form of process is highly complex, uncertain, and non-repeatable; effective methods for design process support must take these factors into account.

1 Processes, Plans and Schedules

A business process is, usually, understood as a sequence of activities, functions or tasks which leads to a well-defined operational goal. Each activity may be viewed as a predictable sub-process transforming knowledge, information, or materials, subject to some set of constraints. Within an organisation, many of these operational goals are pursued simultaneously, leading to the concurrent and overlapping execution of potentially large numbers of processes.

Melo [1] describes a process plan as a general strategy or framework thought to represent the most effective means of reaching the goal. The purpose of a plan is to provide a prescriptive functional framework, in an attempt to predict the future course of the process. Plans may vary in granularity, from staged models centred on the milestones in a design project through to the detailed workflow plans of a repeatable business process, which may include conditional branches to account for activities with more than one possible outcome. This paper is concerned with detailed plans, considering processes at an activity-by-activity level.

Schedules are timetables for the completion of activities. They combine functional activity frameworks with predictions of resource usage and availability. As such, schedules are inevitably more variable than the plans they are derived from.

2 The Process of Product Design

Most business processes are repeatable, and consist of a static framework of activities which operates to transform data or artefacts from one well defined form to another. The form and nature of the transformed items are fixed, as is the need to consider or alter them in a certain and well defined manner. Plans for such processes are typically static, although schedules may vary according to resource availability.

In contrast, design processes are inherently unpredictable, in that completing an activity may reveal shortcomings in the design, throwing it into a less complete state. For example, analysing the flow of air around a turbine blade might reveal that the blade needed to be made longer; but a longer blade requires a larger casing, which in turn requires redesign of many other components. The process is also chaotic, in that the outcome of a design activity completed early in the process may have far reaching and unpredictable consequences later on. For example, two minor components might interact in an unexpected manner which only becomes apparent during pre-production testing, requiring costly redesign.

Planning is further hindered by the non-repeatable nature of design; no product is ever designed twice, since if the product already existed it would be reused rather than redesigned. If a variation of an existing product or subsystem was required, the original would be considered in formulating the new, thus altering the path of the process. In addition, designers are highly skilled and usually specialist; they are interchangeable only to a very limited degree. It may be concluded that design processes require a more flexible and less prescriptive form of support than business processes. Both plans and schedules are dependent upon the current state of the design, and must be frequently updated to remain relevant.

The process of design is inextricably linked to the state of the product under consideration, in that the designer reacts to the aspects of the design under the focus of attention before deciding upon the next appropriate design activity. But by definition, the design is not known until the process is complete, and hence it is difficult to predict or plan the direction a process may take. To compound the problem, the exact nature of an activity is dependent upon the current state of the design and the designer's immediate goal. It has proven difficult to capture the individual activities which are required to formulate a particular design, and composing these activities into a predictive framework is even more problematic.

Organisations are driven by the constant pursuit of many operational goals, each achieved through the execution of a process. These processes are not executed serially or in isolation, but are interleaved in order to reach every goal by its deadline. For example, processing the monthly accounts on time, processing an incoming payment within 24 hours of receipt, and designing a new turbine in 24 months might be three goals requiring overlap between processes. Although all goals are in some sense complementary, the limited resource availability within an organisation causes competition between processes. In other words, one process might consume more than its allocated share of pooled resources, leading to delays in others. Functionally independent processes become interrelated through shared resources, and thus the organisational context must be considered when scheduling; this should be reflected in process support systems.

In many cases, unrealistic expectations coupled with limited resources renders the achievement of every goal on time impossible; in such situations, precedence is given to those goals thought most important to the organisation. For example, resources might be diverted from one project to ensure completion of another. This typically occurs when an important project is due, pulling resources from other processes without regard to the long-term consequences. This uncontrolled competition does not serve the organisation as a whole; 'firefighting' only causes the resource problem to cascade to the next project.

Every organisation must interact with its environment [4]. Resource availability is dependent upon factors outside direct control, such as labour costs and material suppliers. Similarly the set of goals pursued at any one time is unpredictable due to the need for the organisation to transact with the environment; that is, to convert inputs driven by external, unpredictable sources into outputs in some way useful to the business. Goals may be divided into three categories, representing degrees of environmental dependency and process repeatability:

- **Periodic goals** occur at predictable intervals, and their processes are typically repeatable. Examples might include 'process accounts' occurring monthly, or 'prepare for ISO audit' repeating every two years.
- **Event driven goals** are created in response to changes in the external environment, which cannot be predicted and over which the organisation can exert no direct control. An example would be 'process payment', occurring on receipt of payment from a customer. Event driven goals are unpredictable but repeatable; the same process is followed for each occurrence.
- **One-off goals** typically represent large projects initiated within the organisation, perhaps in response to environmental change. For example, 'develop new turbine' or 'implement better process management'. Processes associated with one-off goals are neither predictable nor repeated; these are the most difficult to plan efficiently. In organisations concerned with new product development, the predominance of this type of process presents major planning difficulties.

All three types of goal are likely to occur in any organisation. The unpredictable occurrence of event driven and one-off goals means that a new process might be started at any time, competing for resources and thus affecting existing schedules. Static schedules rapidly become out of date; they must be updated to remain useful. It may be concluded that the organisational context is neither static nor predictable, and thus process support systems should reschedule frequently and automatically.

The arguments made so far have summarised the dependencies between design process plans, the product itself, internal resource availability, and the external environment. In addition, while it is clear that organisations must look across functional boundaries when planning multidisciplinary processes, it is perhaps less obvious that the organisational structure and hence process efficiency is closely tied to the planning strategy.

In practice, products such as gas turbines are too complex to consider as a unit, so they are divided into simpler components to be designed by small teams. This results in a hierarchy of plans which reflects both the component or functional structure of the product and the team-oriented structure of a typical design organisation. Teams plan at a level consistent with the component or function for which they are responsible. The 'Humpty Dumpty School of Organisational Management' argues that this divide and conquer strategy leads to inflexibility and lack of innovation due to the high organisational overheads; in the case of design each team also gains the flexibility to cope with the unpredictable nature of the process.

Unfortunately complex products are often highly integrated and cannot be neatly divided into component hierarchies with well-defined interfaces. Eckert & Clarkson

[5] draw on industrial case studies to show that in practice plans overlap in both function and granularity. Each individual plan is sufficiently simple to be understood and updated manually, but a number must be considered together to maintain overall consistency. This results in high communication overheads between teams, and thus the division of a highly integrated product into sub-components for planning purposes should be carefully considered.

3 Proposed Methods and Models

Many static models, methods and procedures have been proposed for streamlining business processes. Most involve the detailed analysis of existing processes, typically via a functional, task, or activity breakdown, followed by the production of static plans to prescribe an improved process. These 'AS-IS, TO-BE' methods can be effective tools for planning repeatable business processes; the complexity of most organisations means they can always draw benefit from the insights of a targeted analysis. However, their effectiveness in prediction depends upon obtaining a grasp of the entire problem space, such that the activities comprising a particular process can be composed into a rigid prescriptive framework. Static process planning does not easily handle uncertainties or incompleteness in the underlying process model, and as such is not well suited to scheduling processes such as product design.

Representations of the product design process range in complexity from prescriptive staged models through to elaborate descriptive models based on numerical data. Examples of prescriptive models include the waterfall model, which characterizes the process as a series of stages carried out sequentially and isolation, and Ulrich & Eppinger's generic development process [4] which specifies distinct process stages from identification of market needs through to final production. This model, together with Pugh's Total Design model [3], allows for iteration and interaction between the stages. Another example is the spiral model, representing the iterative refinement of the design by the repetition of a sequence of stages.

Prescriptive models are informative and often used when teaching design, but are too abstract to be of practical use. In contrast, descriptive models are based upon representations of concrete processes, with the aim to offer insight and aid decision making for that particular instance. Many examples of descriptive design process techniques involve elicitation and manipulation of one or more Dependency Structure Matrices (DSMs), which are matrix representations of digraph system models. Such methods are popular in industry due to their simplicity and ease of visualisation. Another descriptive technique is Signposting [1], which dynamically organises the process based upon the current level of refinement of the product. These methods require an (often numerical) representation of the process under consideration. Eliciting and validating these representations can be a lengthy and difficult process, and the degree of insight gained is highly dependent upon the skills of the analyst.

4 Conclusion

The process of design is significantly more complex than other business processes, and requires a fundamentally different type of support. Design is unpredictable, complex and chaotic; the creative nature of the process does not allow a prescriptive low-level approach, as often used to streamline business processes. The inherent uncertainty of the process leads to unfeasible schedules and hence to firefighting; these may well be inescapable characteristics of loosely structured processes. Hence design process support tools must suggest rather than prescribe a route through the process, and must be flexible enough to accommodate unexpected changes in direction. They should promote consideration of process context and lead to increased understanding of the relationship between products, processes, and organisation.

This paper has summarised some of the important issues surrounding the process of product design, and briefly introduced a number of proposed process models. Many more models have been proposed, and they vary widely both in depth and in scope. It is not difficult to extend most methods to account for a wide variety of important factors, but the uncertainty of design renders complex representations extremely difficult to elicit, validate and maintain. Hence the real problem lies in formulating the problem itself:

- *What are the requirements for a design process support tool?*
- *What is most important to capture and what should be left out for simplicity?*
- *How are the insights that can be drawn from a particular representation dependent upon the unmodelled aspects of design?*

Answers to these and related questions must be found to define the focus of attention for future support tools, and to ensure such tools are carefully targeted to provide the most benefit to industry.

References

1. Andres Felipe Melo, A State-Action Model for Design Process Planning, PhD Thesis, University of Cambridge, 2002.
2. Karl T. Ulrich & Steven D. Eppinger, Product Design & Development, McGraw-Hill 2000. ISBN 0-07-229647
3. Stuart Pugh, Total Design, Addison-Wesley 1991. ISBN 0-201-41639-5
4. Paul Thompson & David McHugh, Work Organisations 3rd ed., Palgrave 2002. ISBN 0–333-94991-9
5. Claudia Eckert and P John Clarkson, The Reality of Design Process Planning, accepted for the Intrnational Conference on Engineering Design 2003 (ICED ’03).