INTERNATIONAL DESIGN CONFERENCE - DESIGN 2010
Dubrovnik - Croatia, May 17 - 20, 2010.

MODELLING THE DESIGN PROCESS PLANNING SYSTEM

M. P. De Lessio, D. C. Wynn and P. J. Clarkson

Keywords: planning system, modelling, planning elements

1. Introduction

Findings from industry interviews and an industry survey conducted by Cambridge University targeted toward industry employees with responsibilities related to design process, determined that most organisations create multiple plans when conducting a product design project. Over ninety percent of project actors surveyed suggested that they typically reference multiple plans with a significant number suggesting that they reference more than ten planning documents for a typical project. In addition, a majority of respondents reported that the plans referenced are typically created by multiple work teams and/or functional areas both within and outside of the organisation. It was also stated that even though many of the plans were interdependent, changes to plans are most often implemented and communicated manually. This suggests a very high potential to introduce error into affected plans if the dependencies between the interdependent plans are not properly managed when change inevitably occurs. Such planning error can often result in the introduction of project delays or at the very minimal "putting out fire" activities that distract resources from their planned activity causing additional potential for delay.

This paper introduces the use modelling to analyse aspects of the modelling system to minimise the potential for such planning error. Using a dependency structure matrix we will map the relationships between the multiple plans used within the planning system to identify and minimise the opportunity for planning error to occur. Such models can be used to evaluate the overall planning system in multiple ways creating the opportunity to define enhanced methodologies for conducting the highly dispersed but yet very interactive planning activity amongst project actors. As a major element of the overall planning system, we argue that modelling and analysing the multiple interdependencies between plans will enable analysis to recommend how the planning system could be revised for greater effectiveness. Such revision minimises the potential for error and potential project delay and results in a better managed and more successful project. In continuance, an improved planning system would enable managers to better manage and communicate plan changes made within that planning system to all affected parties, ensuring effective co-ordination between the many actors involved in such a project.

2. Background

There has been much written about planning in literature, however, much of what has been written has been skewed toward specific disciplines such as Business and Artificial Intelligence with significantly less literature addressing planning the design process. While there are many planning similarities between the varying disciplines, many authors suggest that there are distinct differences between planning the design process and that of other disciplines. For example, Wynn suggests design processes differ from well-behaved business processes in that they are non-repeatable, unpredictable

and involve complex resource constraints and concludes that this is why many business process planning methodologies are not suited for engineering design [Wynn 2003]. When discussing the design process many authors recognise and allude to the role of planning but do not address it directly. Pahl and Beitz suggest that the Planning and Clarifying the Task phase of their four phased design process model results in a requirements list which then forms the basis for the subsequent design phases. They further discuss the idea of "procedural plans" which they refer to as "operational guidelines for action" that define the working steps for progressing through the design process [Pahl and Beitz 1996]. Ulrich and Eppinger write that planning the design process involves scheduling the project tasks and determining the resource requirements [Ulrich and Eppinger 2000]. They further suggest that the project plan is laid out during the development phase and continues to evolve throughout the design process.
While these authors have embraced the importance of the planning activity in their work they have done so from the perspective of the design process. Industry findings described in the ensuing chapters suggest the need to view the planning activity from a broader perspective. Considering the overall "planning system", which encompasses all aspects of planning associated with a design project, this paper introduces the concept of modelling the planning system which can then be used to analyse and contribute to the planning effectiveness and overall success of a design project.

3. Methodology

A combination of industry interviews and an industry survey were used to generate the findings and proposals presented in this paper. Each interview and survey respondent represents a unique individual or group of individuals from industry. The following sections discuss the data gathering methodologies that were used and the initial conclusions compiled from the data.

3.1 Industry interviews

Table 1 illustrates the industry interviews that were conducted at ten distinctly different engineering organisations. In some cases just one engineer was interviewed and in others multiple engineers with varying responsibilities were interviewed. Targeting a diversity of manufacturing firms, the objective of the interviews was to identify the differences and commonalities between the design process planning activity of organisations producing varied products. The interviews were semi-structured lasting between one and three hours in duration and undertaken with engineering and management personnel from two US telecom companies, one UK telecom company, two divisions each in two UK aerospace manufacturers, a UK cellular telephone manufacturer, and two large EU automotive manufacturers.

3.1.1 Interview methodology

The interviews were conducted as interactive discussions, guided by a series of questions falling into the following main areas:

- Tell me about the products you work on.
- Tell me about how you plan the product design process.
- Tell me about the plans and tools you use for planning the design process.
- Tell me how you feel about the planning activity used for the product design process.
- Tell me if you use advanced tools and methodologies to manage the design process.

Recorded interviews were transcribed and non-recorded interviews were carefully recorded in notes. These transcriptions and notes were then reviewed in detail to identify commonalities around common characteristics. The findings are described in section 4.1.

3.2 Industry Survey

Given the inherent contributions of different data gathering methodologies, an industry survey was also conducted. Characterised by its descriptive nature, simplified application and broad reach, the survey objective was to generate a broader swath of the employee perspective on a much larger scale. Analysing results from the perspective of functional responsibility, management level and industry type across a larger respondent audience would allow for a more thorough analysis of how the different perspectives view the planning activity within their respective organisations. Figure 1 represents the different sections that were included in the survey while the following section describes the reasoning behind each section. To date thirty-four usable responses have been secured although in some instances partial completion resulted in a reduced number of responses for some of the statistics presented.

Table 1. Industry Interview Summary

Industry	*Product*	*Company size*	*Interview format*	*Interview duration*	*Interviewee Description*
Aerospace	Composite Aircraft Structures	>40,000	Telephone	1 Hour	The Technology Manager of their Aerospace Division.
Automotive	Automotive parts and sub-systems	>250,000	Telephone	1 Hour	A member of the corporate research staff after he took the draft industry survey.
Automotive	Truck and Heavy Equipment Engines	> 100,000	In Person	Multiple 2-3 hour interviews	Multiple members with various responsibilities in their Product Planning group, as well as, worldwide IT group head.
Aerospace	Composite Aircraft Structures	>40,000	In Person	3 Hours	A Design Engineer and Program Manager for the Aerospace division.
Telecom	Integrated Voice and Multi-media switches	< 300	In Person	3 Hours	The Directors of Project Management and Software Engineering.
Telecom	Contact Centre Analytic hardware / software system	< 100	Telephone	1 Hour	The Product Manager for their most recent product introduction.
Telecom	Mobile Telephone	>60,000	In Person	2 Hours	A Design Engineer for the UK mobile phone division.
Aerospace	Aircraft components	>100,000	In Person	2 Hours	An Engineering Manager for Business Improvement
Aerospace	Aircraft components	>100,000	In Person	2 Hours	The Chief Technologist – New Product liaison
Electronics	Microscopes	> 300 (Division)	In person	2 Hours	A Software Manager for R&D Development and an Engineering and Technical Support Manager

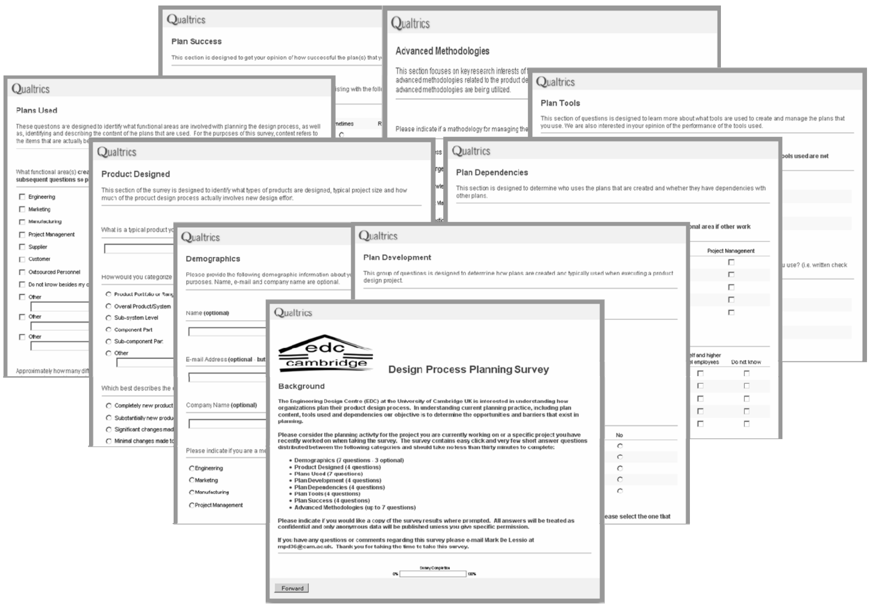


Figure 1. Survey Sections

3.2.1 Survey Design

The survey which can be found at www.designplanningsurvey.com is designed to elicit the planning system followed as viewed from the individual employee perspective. The sections of the survey are designed to elicit a comprehensive story of the individual respondents' understanding of the planning system they use eliciting the relationships between planning activities conducted and planning tools used.

Table 2. Survey Design Summary

Section	*Objectives*
Demographics (8 questions)	Provides demographics of the respondent and the company they work for.
Product Designed (4 questions)	Establishes what types of products are designed, typical project size and how much of the product design process actually involves new design effort.
Plans Used (7 questions)	Identifies who and what functional areas are involved with the design process planning activity, as well as, identifying and describing the content of the plans that are used and the frequency and reason why plans are changed.
Plan Development (5 questions)	Determines who creates plans, when they are used and how they are used.
Planning Dependencies (4 questions)	Identifies who uses the plans that are created and whether they have dependencies with plans used by other functional teams or other functional areas.
Plan Tools (4 questions)	Determines what tools are used to create and manage the plans that you use.
Plan Success (4 questions)	Establishes whether the plans that are created and the tools used to create them are successful from the respondent perspective.
Advanced Methodologies (7 questions)	Determines how aware respondents are of the availability and use of advanced design management methodologies and tools and whether or not they use them or have an interest in using them.

4. Industry findings

While the planning systems in place vary in detail between organisations, the research conducted to date indicates that there are many similarities in the way the design process planning activity is conducted. In addition, while the importance of planning is often alluded to in literature, description of actual planning systems and the manner in which the planning activity is conducted is rarely described. This section describes what this research has determined to date.

4.1 Findings from industry interviews

Industry interviews indicated many similarities between the planning systems of different organisations. While the detail of the systems such as terminology used, plans created and content of plans varied, the overall planning systems had many commonalities. The main commonalities drawn from analysis of the interview notes and transcripts are presented here:

- There was a distinct linear stage-gate based design model forming the basis of the planning system, although the different stages did not necessarily share common names from organisation to organisation. Go, no go gates are typically embedded between the recognised stages within a functional area and somewhat more rigid gates typically exist at the hand off points between functional areas. The go-no go decision is typically based on a check list of criteria that must be met before the project can progress to the next stage.
- Again recognising that different terminologies are used, the organisations interviewed indicated a parallel planning activity between different functional areas. There were several indications that these functional planning activities mostly occurred independently. However, as communication was necessary, the intensity level was usually dependent on the progress along the linear stages. It was indicated that communication regarding plans often

becomes more magnified as the project gets closer to a hand-off between the functional areas in question.

- External factors generated from both outside and within the company can strongly influence the product design process. Very often these factors are not communicated to every agent of interest that should be informed and therefore, become very disruptive to the planning activity that has already occurred. Interviewees believed this had an adverse effect upon planning effectiveness.
- Within all the companies, design iteration is quite common within stages and between gates. There were indications that updating plans to reflect product iterations was not always consistently done resulting in the iterations not being properly communicated to all agents of interest that needed to be informed.
- It is common for very many specific planning documents to be created during a typical project. One interviewee identified over fifty planning documents used during the typical product design process spread across the parallel functional areas involved with the project.
- The tools used to create the planning documents utilised were often off-the-shelf tools such as the Microsoft suite of management tools. Other more specific tools were used but not always consistently between project agents and often outside the planning activity conducted.

4.2 Findings from industry survey

Coming from more of an individual employee perspective as opposed to an organisational view, the survey findings provided both verification and complementary findings to those of the interviews. The conclusion garnered from the initial survey findings suggest some clear planning patterns across organisations in the creation, content, use and interdependency of plans.
Figure 2 demonstrates the multiple functional areas that typically create plans for a design project. It also states that customers, suppliers or both are often very involved in the project planning activity. Finally, it suggests that actors often create their own plans based on the plans they reference.

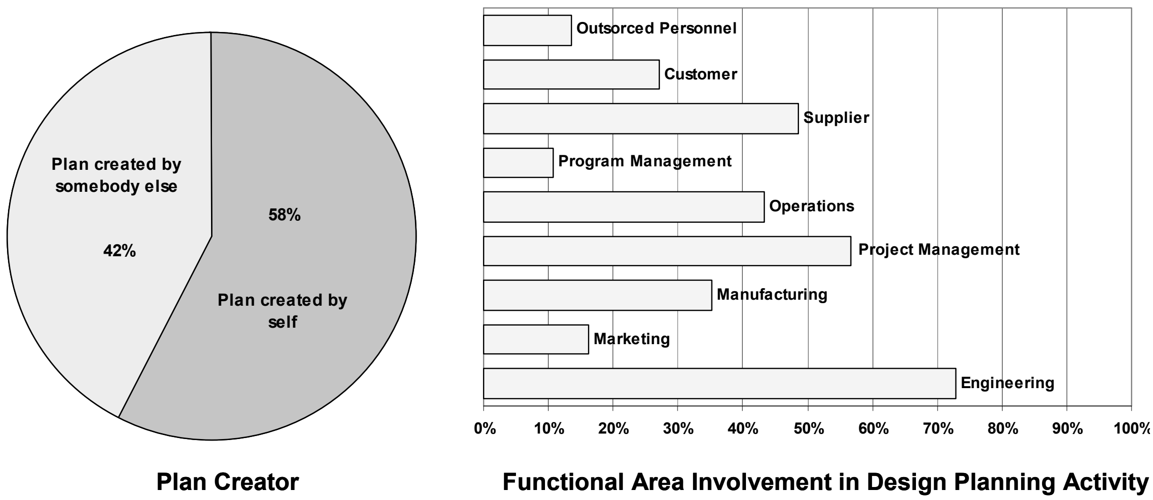
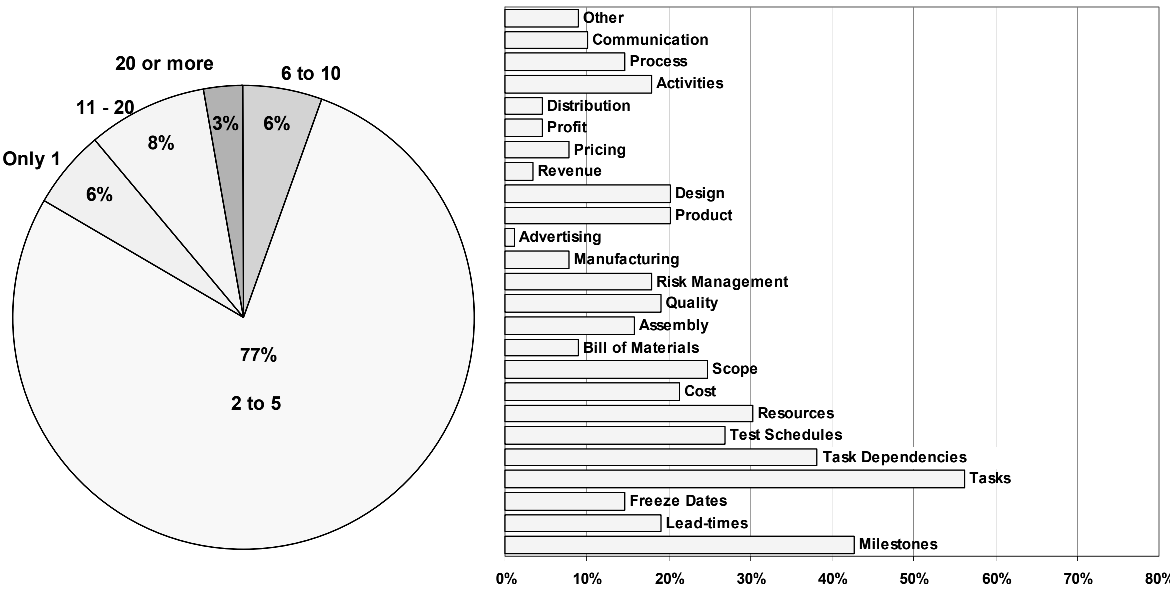


Figure 2. Plan Creation

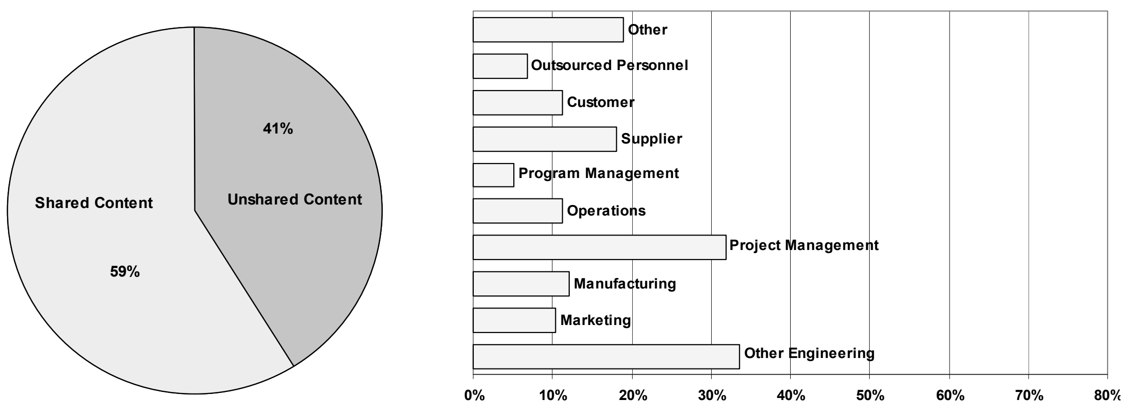
Figure 3 indicates that a large majority of project actors reference multiple plans for a typical project. Included in these plans is a large variety of content which is very often at least partially duplicated between different plans.



Plans Used per Respondent **Percent of Plans with Stated Content**

Figure 3. Plan Content

Figure 4 indicates that plan content is often shared amongst multiple plans. It also suggests that this content is usually shared with other teams within the same functional area, other functional areas, customers and suppliers.



Content Shared Between Plans **Percent of Plans Dependent on Other Functional Area Plans**

Figure 4. Plan Dependencies

Lastly, figure 5 indicates that the majority of dependent plans are updated frequently and that most often those updates are conducted manually and in some cases simply not coordinated.

4.3 Summary

Although the companies studied differed significantly in terms of size, location and sector, the interviews and survey results revealed that there were many characteristics that their respective planning systems shared. Perhaps most importantly, both the interviews and the survey highlight the complexity of the planning system and the many interdependencies between the planning system elements. The next section explores the opportunities to model these complex dependencies as a means to identify opportunities for optimising the planning system and increasing its value to the design organisation as a design project tool.

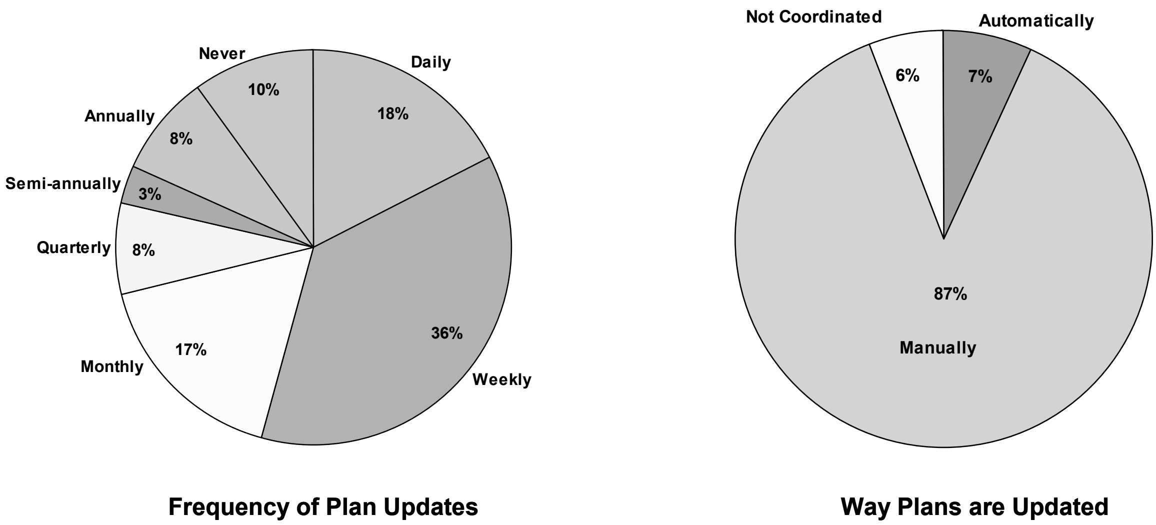


Figure 5. Plan Changes

5. The planning system

Planning is considered an integral part of most projects and the design process is no exception. However, while the planning activity seems grandiose in stature at the beginning of a project it is quite often delegated to not much more then a tick box fragmented activity as the project ensues. The Oxford Dictionary describes a system as "a set or assemblage of things connected, associated, or interdependent, so as to form a complex unity" [Oxford 2009]. While this term is commonly used, in design literature, to describe the overall product it is rarely used in reference to the planning activity. This paper introduces the concept of a planning system, which encompasses all planning activity associated with a specific project. We propose that by modelling the planning system, optimisation opportunities can be identified and the planning system can be more readily used as a valuable resource for managing the successful completion of a design project.

5.1 Modelling the planning system

Much of the design literature has focused on modelling the design process itself. As early as 1971, French proposed a linear four-phase process design model based on the design practice observed in industry and many have emulated his model in their own work since then [French 1998]. Other authors expanded on linear stage-gate models to recognise all the factors that influence the design process. For example, the model presented by Hales indicates that the "resolution" and "viewpoint" taken of a project could have significant impact on the planning activity [Hales 2004]. For example, what is included in a plan will likely result in significantly different opinion when considered from the Marketing resolution versus the Engineering resolution, as well as from the engineer viewpoint versus the senior management viewpoint. Still other authors have proposed using modelling as a tool to make the design process more efficient and ultimately successful. Much has been written on the use of Design Structure Matrix (DSM) and House of Quality to model the dependencies of product components or project tasks related to a design process or project.

The remainder of this paper strives to argue how modelling can be used to analyse the planning system. Modelling the actual planning system has rarely been attempted in literature. De Lessio et. al. proposed a high level model of the design process planning system shown in Figure 6 and based on industry interviews with a variety of organisations [De Lessio et. al. 2009]. While this model represents a specific view of the design process planning system it is and was intended to be generic to any specific organisation. Eckert adds a level of detail in figure 7 with her model representations of the planning activities of one organisation [Eckert 2009]. In these models Eckert shows the dependencies between plans, as well as both direct and indirect ownership. However, such static models are only representative. While such representative views are highly valuable to organisations we are proposing to take modelling a step forward and use it as a valuable assessment tool of the planning system.

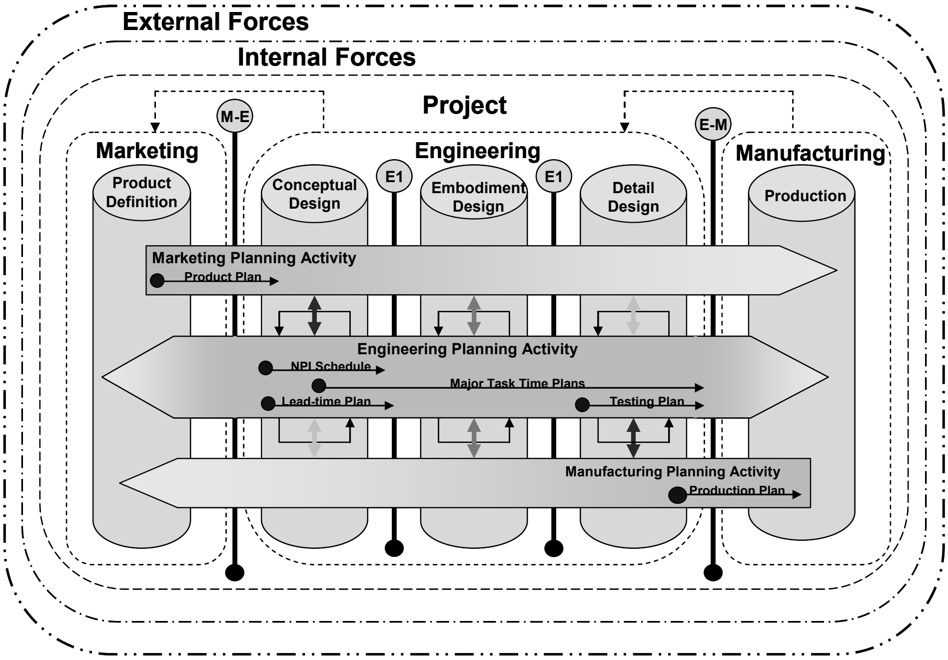


Figure 6. High Level Planning System Model

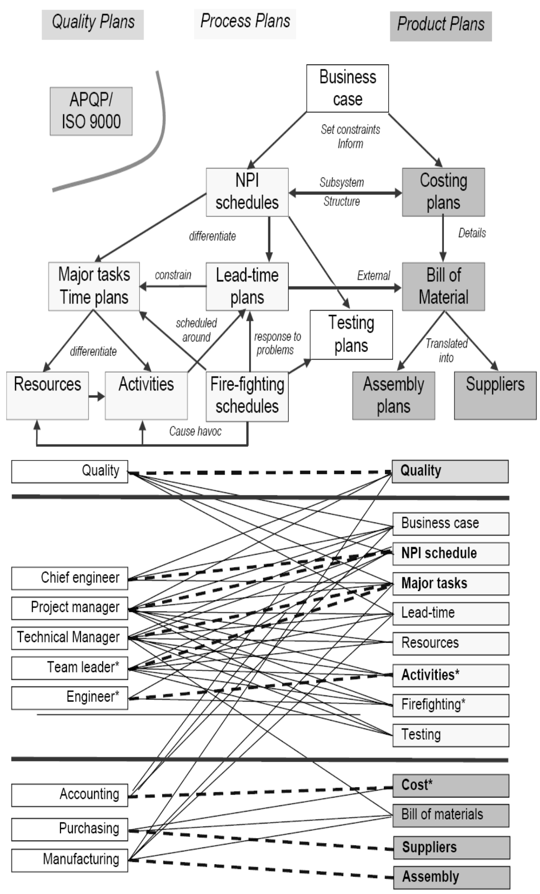


Figure 7. Specific Planning System Model

5.2 Using modelling to optimise the planning system

The planning system for a product design project is, in many ways, as complex as the product being designed. There are often multiple interdependencies between the many elements involved including the following:

- Plan content
- Actor involvement
- Team involvement
- Functional area involvement
- Management level involvement
- Design stage involvement
- Hardware versus software

These interdependencies are further complicated by additional design project characteristics such as project size and frequency of plan updates and yet even further complicated by the actual type of interdependency that exists such as symmetrical versus asymmetrical and direct versus indirect. Given the inevitable characteristics of uncertainty, design iteration and product change for design projects, such connectivity between the multitudes of plans typically created suggest real opportunity to derail a project when the impact of inevitable change is not properly considered for all its possible consequences. The difficulty of managing changes is an example of one such consequence which often relegates plans to little more then a tick box exercise that become increasingly under utilised or ignored as a project endures.

Demonstrating one example of how modelling can be used, this paper uses modelling to analyse the varying dependencies that exist between the many plans that are typically developed for a design project. Such analysis will enable better management of the many planning dependencies that will likely be affected when inevitable change does occur resulting in a better communicated and more successful project. The following section provides an illustrative example of how modelling can be used to identify possible opportunities to improve the embedded planning system.

6. Illustrative example

Understanding the interdependencies between plans can greatly impact a project manager's ability to manage a design project. Browning writes that products, processes and organisations are each a kind of "complex system" and further suggests that the classic approach to understanding complex systems is to model them [Browning 2001]. Earlier in this paper we proposed that the planning system was in itself a complex system. Emulating Browning, this section will demonstrate how modelling will result in a better comprehension of the planning system. The survey result from a senior member of a ship building organisation is used to demonstrate how this objective can be achieved.

6.1 Building the model

A Multiple Domain Matrix (MDM), shown in Figure 8, is used to analyse the interdependencies of multiple planning system elements including the plans used, the plan content and the functional areas that use the plans. Going down the right side, the plans listed by the respondents are group together first. This is followed by the suggested content of those plans, which is highlighted in a lighter grey and finally, the functional areas that use the plans are grouped together last. The content and functional areas were selected from provided lists, however the respondent could also enter an item not listed. The darker grey areas marked in X show what plans contain what content and the lighter grey areas marked in X show what functional areas use what plans as indicated by the respondent. The values for the plan comparison were determined by calculating how many content items the two plans being compared have in common. The values for the content comparison were derived by determining how often the two being compared were included in the same plan. Finally, functional area comparison values were determined by analysing what plans are used by the functional area and how many content items are included in those plans. We propose that the extremities in the scoring identify characteristics of the planning system that potentially deem further analysis and possible actions to be taken.

	Proj. Mgmt. Plan	Qual. Mgmt. Plan	Eng. Mgmt. Plan	OEM Plan	Customer Plan	Milestones	Lead-Times	Freeze - Dates	Tasks	Test Schedules	Resources	Cost	Bill of Materials	Assembly	Quality	Risk Mngt.	Manufacturing	Product	Design	Revenue	Pricing	Profit	Activities	Process	Communication	Engineering	Manufacturing	Customer	Supplier	Outsourced Personnel
Proj. Mgmt. Plan		7	10	12	9	X	X	X	X		X	X			X	X				X	X	X	X	X	X	X	X	X	X	X
Qual. Mgmt. Plan	7		8	8	8	X			X	X					X	X							X	X	X	X	X	X	X	X
Eng. Mgmt. Plan	10	8		16	12	X	X	X	X	X			X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X
OEM Plan	12	8	16		13	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X		X	X	X
Customer Plan	9	8	12	13		X			X	X		X			X	X	X	X	X	X	X	X	X	X	X	X		X		
Milestones	X	X	X	X	X		3	3	5	4	2	3	2	2	5	5	3	3	3	4	2	2	5	5	5	5	3	5	4	4
Lead-Times	X		X	X		3		3	3	2	2	2	2	2	3	3	2	2	2	3	1	1	3	3	3	3	2	3	3	3
Freeze - Dates	X		X	X		3	3		3	2	2	2	2	2	3	3	2	2	2	3	1	1	3	3	3	3	2	3	3	3
Tasks	X	X	X	X	X	5	3	3		4	2	3	2	2	5	5	3	3	3	4	2	2	5	5	5	5	3	5	4	4
Test Schedules		X	X	X	X	4	2	2	4		1	2	2	2	4	4	3	3	3	3	1	1	2	2	2	4	2	4	3	3
Resources	X			X		2	2	2	2	1		2	1	1	2	2	1	1	1	2	1	1	2	2	2	2	1	2	2	2
Cost	X			X	X	3	2	2	3	2	2		1	1	3	3	2	2	2	3	2	2	3	3	3	3	1	3	2	2
Bill of Materials			X	X		2	2	2	2	2	1	1		2	2	2	2	2	2	2	0	0	2	2	2	2	1	2	2	2
Assembly			X	X		2	2	2	2	2	1	1	2		2	2	2	2	2	2	0	0	2	2	2	2	1	2	2	2
Quality	X	X	X	X	X	5	3	3	5	4	2	3	2	2		5	3	3	3	4	2	2	5	5	5	5	3	5	4	4
Risk Mngt.	X	X	X	X	X	5	3	3	5	4	2	3	2	2	5		3	3	3	4	2	2	5	5	5	5	3	5	4	4
Manufacturing			X	X	X	3	2	2	3	3	1	2	2	2	3	3		3	3	3	1	1	3	3	3	3	1	3	2	2
Product			X	X	X	3	2	2	3	3	1	2	2	2	3	3	3		3	3	1	1	3	3	3	3	1	3	2	2
Design			X	X	X	3	2	2	3	3	1	2	2	2	3	3	3	3		3	1	1	3	3	3	3	1	3	2	2
Revenue	X		X	X	X	4	3	3	4	3	2	3	2	2	4	4	3	3	3		2	2	2	2	2	4	2	4	3	3
Pricing	X				X	2	1	1	2	1	1	2	0	0	2	2	1	1	1	2		2	2	2	2	2	1	2	1	1
Profit	X				X	2	1	1	2	1	1	2	0	0	2	2	1	1	1	2	2		2	2	2	2	1	2	1	1
Activities	X	X	X	X	X	5	3	3	5	4	2	3	2	2	5	5	3	3	3	2	2	2		5	5	5	3	5	4	4
Process	X	X	X	X	X	5	3	3	5	4	2	3	2	2	5	5	3	3	3	2	2	2	5		5	5	3	5	4	4
Communication	X	X	X	X	X	5	3	3	5	4	2	3	2	2	5	5	3	3	3	2	2	2	5	5		5	3	5	4	4
Engineering	X	X	X	X	X	5	3	3	5	4	2	3	2	2	5	5	3	3	3	4	2	2	5	5	5		38	71	56	56
Manufacturing	X	X	X			3	2	2	3	2	1	1	1	1	3	3	1	1	1	2	1	1	3	3	3	38		38	38	38
Customer	X	X	X	X	X	5	3	3	5	4	2	3	2	2	5	5	3	3	3	4	2	2	5	5	5	71	38		56	56
Supplier	X	X	X	X		4	3	3	4	3	2	2	2	2	4	4	2	2	2	3	1	1	4	4	4	56	38	56		56
Outsorced Persone	X	X	X	X		4	3	3	4	3	2	2	2	2	4	4	2	2	2	3	1	1	4	4	4	56	38	56	56	

Figure 8. Multiple Domain Matrix

6.2 Analysing the model

In this example the interdependencies between the planning system elements were analysed based on their commonalities with each other. While there is a fairly high degree of interdependency between all the planning elements, in this case, it does suggest some items of note:

- There is a high degree of dependency between the Engineering Management Plan and the OEM Plan (highlighted with a score of 16). While this is quite logical it suggests that activities that affect one plan should be timely communicated to the actors responsible for the other plan.
- There is a very low degree of dependency between plans addressing pricing and profit content and plans addressing bill of materials content (highlighted with a score of 0), which seems somewhat unusual and perhaps suggest that a review should be undertaken to determine if there is reason for concern.
- There is a high degree of dependency between plans that manage milestone, tasks, assembly, risk management, activities, process and communication (highlighted with a score of 5)

which is also very logical and suggests that actions taken to any of these plans should be communicated to the actors responsible for the other plans.

- There is a high degree of dependency between the Engineers and the Customer (highlighted with a score of 71) suggesting there should be ample communication between the two groups through both the planning activity and perhaps verbally.

6.3 Summary

This example demonstrates how the survey results can be utilised to model the planning system from the perspective of an individual employee. Considering that it is based on the result of just one survey, it is easy to see how such an exercise could have significant value when derived from a survey of multiple employees in the same organisation from different functional areas and different levels of management. While this is a fairly straightforward analysis it does demonstrate the opportunities to use modelling to analyse the planning system and sets the basis on which our future work will build.

7. Conclusion and future work

Planning is an integral part of the complex product development system. While recognised as important by many author, the planning system itself is often casually alluded to in most publications in favour of focusing on the particular tool or methodology being discussed. Our initial industry findings also suggest that the planning system is often under valued in industry and viewed as more of a nuisance than a valuable resource. Drawing on these findings, we concluded that there is scope to further research how the planning system can be better utilised to effectively manage design projects. This paper proposes one example of how modelling can be used to obtain this objective. Using a simple MDM model, we have demonstrated how important elements of the planning system can be analysed to identify notable characteristics of the planning system that could possibly impact the design project. This paper focuses on the interdependencies of planning elements which is an important aspect of the overall planning system. It is our intention to build on this concept to explore the greater intricacies between the multiple elements that make up the planning system as a means of optimising the planning system. It is are goal to achieve a level of optimisation that that minimises planning activity while maximising planning efficiencies amongst all project actors regardless of responsibility, functional area or level of management. We intend to apply different modelling techniques to determine which techniques offer the best opportunities to achieve our stated objective. It is our view that such a systematic approach of modelling planning system element interdependencies, identifying planning system optimisations and utilising the planning system as an effective project management tool will enable industry to maximise overall design project success.

References

Browning, T. R. " Applying the Design Structure Matrix to system decomposition and integration problems: A

De Lessio M.P., Wynn, D. C., Clarkson, P.J., "Communication and Design Process Planning: Initial Insights from Literature and Industry Interviews" Proceedings of the 17th International Conference on Engineering Design – ICED 2009, Stanford 2009.

Eckert, C.M.., Clarkson, P.J., "Planning development processes for complex products", Research and Engineering Design,Vol. 20, No. 4., 2009, pp 201-264

Review and New Directions", IEEE Transactions on Engineering Management, Vol.48, No.3,2001, pp 292-306.

French, M., "Conceptual Design for Engineers', 3rd Ed., Springer-Verlag London UK, 1998.

Hales, C., "Managing Engineering Design, 2nd Ed.", Springer-Verlag London UK, 2004.

Pahl, G. and Beitz W., "Engineering Design: A Systematic Approach, 2nd Ed.", Springer-Verlag London UK, 1996.

Little, W., Fowler, H.W., Coulson, J., "The Shorter Oxford Dictionary", Oxford University Press London UK 1973.

Ulrich, K.T, Eppinger, S.D., "Product Design and Development, 2nd Ed.", McGraw-Hill Education London UK, 2000.

Wynn, D.C., "Capturing Complex Design Processes: Ph.D. First Year Report", University of Cambridge, 2003.

Mark Philip De Lessio
PhD Student
University of Cambridge, Engineering Design Center
Trumpington Street, Cambridge, UK
Telephone: +44 (0) 1223-748563
Telefax: +44 (0) 1223-332804
Email: Mpd36@cam.ac.uk
URL: http://www-edc.eng.cam.ac.uk/people/mpd36.html