INTERNATIONAL DESIGN CONFERENCE - DESIGN 2016
Dubrovnik - Croatia, May 16 - 19, 2016.

PLANNING THE PRODUCT DESIGN PROCESS

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Keywords: product design process, planning system, planning activity

1. Introduction

Much has been written in literature regarding planning. The plethora of literature available is varied and broad in scope, ranging from pure planning theory to specific planning problem app.lications. The scope of app.lication is equally as broad and varied with many authors writing from the perspective and context of a specific planning requirement. Often in such instances, specific planning requirements are identified and potential solutions are proposed. As such, this paper specifically examines planning from the perspective and context of the complex product design process. Complex is clarified here as referring to multi-component product design projects that require numerous interactions between stakeholders, project tasks and planning documents.
Findings from an industry survey targeted toward employees with responsibilities related to the design process, confirm that the planning activity associated with such projects is often as complex as the projects being pursued. Assessed from the perspective of functional responsibility related to the product design process, a majority of project actors suggested that they typically reference multiple plans in each of the multiple projects they are responsible for. In addition, the plans are typically used to reference a wide variety of content and are often dependent on other plans associated with each project.

2. Planning

New product design and development is most often a critical element of the long term organizational strategy and usually considered at the strategic planning level. However, the planning activity associated with the complex product design process offers unique characteristics from that of other planning activities within the organization. While, perhaps too specific for theoretical suggestion on its own, an interest exists in understanding how the planning activity on such complex design projects have been influenced by broader scoped planning focus such as planning theory and the overall organizational planning system.

2.1 Planning theory

Much theory has been proposed in literature regarding planning. Allmendinger states that it is a truism that planning is comprised of an eclectic collection of theories drawing upon a wide range of different disciplines [Allmendinger 2002]. Although the amount of planning theory literature is vast, the existence of literature directly related to the product design process planning activity is decidedly more limited when compared to other disciplines. While it is difficult to describe planning or even the concept of plans in simple terms, it can be argued that the definition of planning is very dependent on what the actual planning app.lication is. Much of the literature available on "planning theory" is proposed from the perspective of "public planning problems" or "private planning problems". Rittel and Webber famously debated this issue in their paper describing the differences between "wicked problems", which

they associated with public and social policy, to "tame" or "benign" problems associated with the natural sciences [Rittel and Webber 1973]. Galloway and Mayhani express skepticism regarding formation of a general theory of planning to suggest that a planning action cannot be considered in isolation from the object that is being planned [Galloway and Mayhani 1977].
The problem being considered here is the complex product design process, which is often characterized by an extensive network of interactive diverse units that must come together to meet the common objective of a single product design. Epp.inger and Salminen describe the development of complex products and large systems as highly interactive social processes involving hundreds of people designing thousands of interrelated components and making millions of coupled decisions [Epp.inger and Salminen 2001]. Given this extended social characteristic of the complex product design process, it is reasonable to consider that such projects are more similar to a "wicked problem" than normal business processes. Rittel and Webber describe the "social context" of wicked problems by suggesting societies are becoming increasingly differentiated, comprising thousands of minority groups, each joined around common interests, common value systems, and shared stylistic preferences that differ from those of other groups [Rittel and Webber 1973]. It is suggested here that the inherent characteristics of the extended complex product design process similarly shares the sentiment proposed by Rittel and Webber. Wynn implies this when he suggests that design processes differ from well-behaved business processes [Wynn et al. 2003]. He continues that unlike business processes which are repeatable and consists of a static framework of activities, design processes are inherently unpredictable in that completing an activity may result in a less complete state. He concludes by suggesting that design processes need a more flexible and less prescriptive form of supp.ort than business processes require.
With such vague app.lication of any specific planning theory to the complex product design process it is perhaps more logical to consider the complex product design process from the perspective of its inherent environment, the extended organization.

2.2 Planning within the organisational system

Kast and Rozenzweig suggest that organizations are like organisms in that they can be conceived of as sets of interactive subsystems which can be defined in many ways [Kast and Rozenzweig 1973]. They further suggest that organizations have structure that is defined by events as opp.osed to physical components and therefore cannot be separated from the processes of the system [Kast and Rozenzweig 1973]. As a critical process of the organization, it is logical to surmise that the product design process is a subsystem in its own right of the larger organizational system. Maier suggests that product design is an autopoietic social system, which is open for information but "acts upon" information based on its own internal structure and logic of operations [Maier et al. 2005]. She continues by suggesting that external forces might influence the system directly but they cannot control the resultant operations. When examining a typical product design project such a description proves accurate. While the overall project itself is a fairly closed system there is ample social interaction amongst the stakeholders involved. A typical design project includes multiple functional areas contributing its unique output to the overall design project. Each functional area includes specific work responsibilities, which come together to produce the required output. Each work responsibility is the responsibility of a small group or individual stakeholders. In addition, each project has unique external influences, whether from within the organization or external to it, that is most often also the responsibility of small groups or individual stakeholders. Each of these individuals impacts or is impacted by other stakeholders involved with the project. As such this paper examines how much individual expression of interaction related to the complex product design process is realized via the planning system and associated planning activity.

2.3 Planning activity

Ackoff describes planning as "a process that involves making and evaluating each of a set of interrelated decisions before action is required, in a situation in which it is believed that unless action is taken a desired future state is not likely to occur, and that, if app.ropriate action is taken, the likelihood of a favorable outcome can be increased" [Ackoff 1970]. Weber suggests that planning is a special way of deciding which specific goals are to be pursued and which actions are to be taken [Weber 1963]. While varied based on specific app.lication, many authors, from different disciplines, present a similar

sentiment regarding planning. All invoke the inherent characteristics of problem solving through coordinated action. Like most organizational processes, the design process planning requirement is a subset of the larger organizational planning system and thus subjected to the characteristics and maturity level of the planning system in place. While consideration of how specific planning system characteristics and maturity level affects the design planning activity is beyond the scope of this paper it does beg the question of whether planning practice can be app.lied equally and indifferently between the complex product design process and other types of processes functioning within the same planning system.

Wynn suggests that design processes differ from well-behaved business processes in that they are non-repeatable, unpredictable and involve complex resource constraints [Wynn et al. 2003]. Roelofsen et. al. cite the four levels of decomposition proposed by Lindemann [2007] to assess the product design process planning activity which include the strategic process level, project level, operational level and action level. They continue that the strategic level and action level are irrelevant in that the strategic level does not allow for specific planning while planning on the action level will lead to overwhelming planning complexity [Roelofsen et al. 2007]. Instead process planning should take place on the project and operational level continuously switching between the two and based on the situation describing parameters of each level. Acknowledging the iterative nature of product design, Wynn and Clarkson describe three components of the planning activity which includes planning, monitoring and re-planning [Wynn and Clarkson 2009]. They further suggest that the basis for these three components is a schedule of work that must be expressed in plan-level terms by decomposing the design process into tasks, identifying a sequence of attempting those task and scheduling the times when each task should be completed. Hayes-Roth suggests what she termed "the impact of individual differences on planning methods" as one of the variables that affect a planner's app.roach to planning [Hayes-Roth 1979]. To that end, this paper profiles some of the findings garnered from and industry survey regarding the complex product design planning activity from the specific stakeholder perspective.

3. Methodology

An industry survey was used to supp.ort the findings and proposals presented in this paper. Coined as the Planning Management Assessment Survey Tool (PMAST), the survey was developed based on the findings of a thorough literature review and industry interviews. Characterized by its descriptive nature, simplicity and broad reach, the primary objective was to develop a tool that could be used to analyze the planning activity of a specific population. The relative ease and efficiency of retrieving potentially large amounts of specific data from almost any population is a primary advantage of surveys [Robson 2002]. The objective of app.lying PMAST to a general population was to gather enough responses to ensure a viable analysis of the findings. The data standardization and quantitative nature of surveys proved very conducive in establishing qualitative patterns of planning practice across the participant community. The primary goal was to develop a general understanding of how organizations plan their complex product design process based on individuals with specific design process functional responsibility.

3.1 PMAST design

PMAST was designed to elicit the planning activity used to manage overall design projects and day to day responsibilities as viewed by the individual project stakeholder. Each section of PMAST, while specific in nature, is designed to distil a key characteristic of the overall planning activity being conducted. Understanding key characteristics of the planning activity enabled insight into the overall planning system. PMAST utilizes a funneled app.roach, which is sectionalized around blocks of questions that specifically pertain to the research questions posed. The funneled app.roach, in this instance, suggests that feedback obtained in the early survey sections feeds into and directs the questions that are used in ensuing sections. Relative to surveys, this ability is called piping and was a critical feature requirement of the software tool used to create PMAST.

PMAST's content is designed to enable the analyzed results to define clear characteristic patterns around the planning system in use. The section blocks themselves and the questions within each section block are arranged in a specific order to enhance the quality of the responses. Grouping questions that are similar makes the questionnaire easier to complete and the respondent more comfortable [Walonick

2004]. The wording of the questions is also carefully constructed to ensure understanding and ease of answering. In addition, hyper-links to key word definitions were included to ensure consistency of key term understanding between respondents. "One standard for a good question is that all the people answering it should understand it in a consistent way and in a way that is consistent with what the researcher expected it to mean" [Fowler 1995]. Closed-ended questions, where all the choices are known and some strategic open-ended questions, which allow the user to respond in their own words [Waddington 2000], are app.lied respectively, where they are most app.ropriate. The close-ended questions used are multiple-choice and matrix type questions. Forty-five questions including demographic related questions but excluding the PMAST feedback questions were included. Table 1 gives a description and objective of each section included in PMAST. Not all of the survey sections included are being profiled in this paper.

Table 1. Survey design summary

Section	*Objectives*
Demographics	Provides demographics of the respondent and the company they work for.
Product Designed	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	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	Determines who creates plans, when they are used and how they are used.
Plan Dependencies	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	Determines what tools are used to create and manage the plans that you use.
Plan Success	Establishes whether the plans that are created and the tools used to create them are successful from the respondent perspective.
Advanced Methodologies	Determines how aware respondents are of the availability and use of advanced design process management methodologies and tools and whether or not they use them or have an interest in using them.

3.2 Survey execution

The survey was distributed via the website www.designplanningsurvey.com and direct e-mail requests to specific respondents. In a stratified random sampling, one thousand four hundred and twenty-nine (1,429) personal e-mail requests were sent to individuals with product design responsibilities. Stratified random sampling involves dividing the population into a number of groups or strata where the different group members share a particular characteristic [Robson 2002]. In this instance the common characteristic was described as "having responsibilities for the complex product design process". While it is typical to have proportionate sampling for each strata based on the percentage of the strata in comparison to the total population, disproportionate sampling was used here given the difficulty of deciphering an exact break down of the much larger design process population. As such, factual statement of the findings is not proposed, however, it is felt that, for the purposes of this paper, the findings do indicate reasonable representation for comparison purposes regarding the different sub-groups involved in the product design process. The sub-groups that were considered for this paper were divided between functional areas.

Specific Linked-in work groups with new product design and development associations were leveraged to reach the target audience. While total membership numbers are dynamic, the total membership of the four groups was twenty-seven thousand six hundred sixty-one (27,661) during the time the survey was conducted. The targeted groups were specifically targeted to get a cross section of functional responsibilities related to new product design including Engineering, Project Management, Product Management (Marketing) and Manufacturing. A personal e-mail request was sent to each targeted

respondent requesting their participation in taking PMAST. In total, three hundred and twenty-four (324) contacted individuals viewed the survey upon receiving the e-mail and one hundred and twelve (112) individuals completed the entire survey. Four completed responses were eliminated due to suspect data entry when reviewed more thoroughly. The sectionalized design of PMAST enabled the ability to scrutinize data entries that were consistent and most likely based on the best understanding of the respondent. Given the actual figures that resulted, including a population of twenty-seven thousand six-hundred and sixty-one (27,661) and a response rate of one-hundred and eight (108) used responses provides less than a 10% error rate at a 95% confidence level. This suggests that it is reasonable to be 95% confident that the results of the survey have less than a 10% error. These figures do not vary much if the total population is projected over the much larger worldwide design community. Therefore, while the slightly higher error rate perhaps prohibits the suggestion of this research as being a factual representation of the product design community, as a whole, it is an effective representation for the purposes of this paper.

The following section provides a quantitative representation of the general qualitative findings of the completed data for all respondents. Comparisons of multiple respondent sub groups such as functional responsibility are made to enable additional assessment of the overall complex product design planning activity picture.

4. Industry findings

Coming from an individual stakeholder perspective, the industry wide PMAST findings provide an informative perspective of the product design process planning activity across multiple functional responsibilities. This section begins with a demographic profile of the respondents who participated in the industry wide study. It then describes the analyzed results for each of the major characteristic blocks that are included in PMAST. When viewed from the perspective of the whole respondent population, the conclusions garnered from the survey findings suggests some common planning patterns across organizations in the creation, content, use and interdependency of plans.

4.1 Demographics

A very diverse group of individuals participated in the industry wide PMAST study. In all, twenty-seven different countries are included with the highest representation coming from the United States, India, United Kingdom and Canada, respectively. Figure 1 indicates how the respondents classified their functional responsibility which will be used for comparative analysis with the intention of highlighting key planning system characteristics.

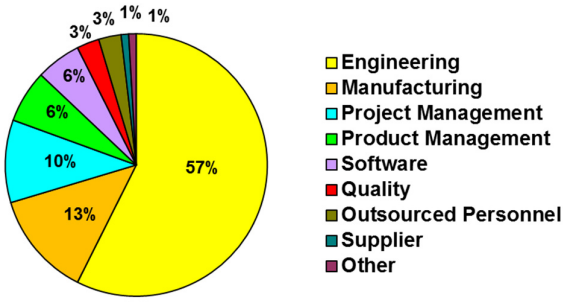

Figure 1. Respondent functional responsibility

Comparisons will be made between the functional groups of engineering, project management, product management (marketing), manufacturing and other sample groups. The "other" group includes more specialized personal including those respondents who classified themselves as software specialist, quality specialist, outsourced personnel and supp.liers. Functional responsibility was self-identified by the respondents. As such, it is deemed, for example, that individuals included in the project management category had responsibilities which included leading teams responsible for meeting design project objectives [PMBOK 2013]. It must be noted that some of the functional sample groups are considerably

smaller than that of the engineering group itself. For this reason factual app.lication to industry as a whole is not being suggested but it is felt that the analysis is still valuable for comparison purposes.

4.2 Plan use and creation

The use of multiple plans is consistent for all functional areas responsible for the design process, which is indicated in Table 2. A strong majority for each of the functional areas indicated the use of as many as ten plans for each design project. Further analysis (data not shown) also indicated that each of the functional areas also indicated the use of a master plan as most often the most important plan used (68% for Engineers, 89% for Project Managers, 67% for product management, 86% for manufacturing and 64% for the other group). Each also indicated that a significant number of the plans created are used for all stages of the design project (36% for engineering, 33% for project management, 27% for product management, 38% for manufacturing and 23% for the other group). Finally, all functional areas indicated significant use of the plans referenced were used to make go/no go decisions (61% for engineering, 67% for project management, 77% for product management, 70% for manufacturing and 52% for the other group).

Table 2. Plans used per project

	Engineering	Product Management	Manufacturing	Other	Project Management
Only one	10%	0%	7%	7%	0%
Two to five	55%	67%	43%	64%	37%
Six to ten	17%	33%	29%	14%	27%
Eleven to twenty	5%	0%	0%	0%	18%
More than twenty	10%	0%	21%	7%	18%
Do not know	3%	0%	0%	7%	0%

The use of multiple plans for the same project immediately suggests a complexity in how individual design project stakeholders conduct the planning activity for managing the projects being worked on. This complexity is magnified when the number of projects worked on is considered. Table 3 indicates the number of projects that a single stakeholder typically works on. Despite functional responsibility most stakeholders involved with product design work on multiple projects that typically use unique plans. This multi-project finding is consistent with that stated in literature. In analyzing R&D organizations, Turner and Speiser suggest that a vast majority of projects take place within programs of related small to medium sized projects [Turner and Speiser 1992].

Table 3. Projects worked on

	Engineering	Product Management	Manufacturing	Other	Project Management
Just one	13%	0%	0%	21%	18%
Up to three	52%	50%	21%	50%	64%
Up to five	27%	33%	57%	21%	0%
Up to ten	3%	0%	7%	7%	9%
More than ten	2%	0%	7%	0%	9%
Other	3%	17%	7%	0%	0%

It is proposed that considering who actually creates the plans that are being used may give some insight to the level of difficulty involved with managing the multi-plan, multi-project planning activity complexity. Logic suggests that if individuals are creating and maintaining the multiple plans they use it would help minimize managing the interdependencies between them by minimizing the need to consult with other project stakeholders and planning sources. Table 4 indicates that a significant percentage of respondents for each functional area create their own plans, with the Project Management group indicating the highest percentage as might be expected. While a large percentage of plans used are being created by the project stakeholders using them there is still a significant number of plans being

used that are actually the responsibility of another individual or work team. This was particularly true for the product management sample group.

Table 4. Plans created by self

	Engineering	Product Management	Manufacturing	Other	Project Management
Yes	49%	31%	58%	62%	74%
No	30%	58%	27%	22%	18%
Sometimes	21%	12%	16%	17%	8%

Several observations can be made based on these answers. On one hand the results verify the insular aspect of the planning activity from an individual stakeholder perspective which suggests that the difficulty in coordinating plans used is partially minimized because they are being created and managed by the same individual. However, they also suggest that there is still a significant external influence on the planning activity for the typical design project stakeholder.

4.3 Plan content

Table 5. Stakeholders who manage plan content

	Engineering	Product Management	Manufacturing	Other	Project Management
Milestones	75%	50%	86%	64%	91%
Lead-times	60%	50%	50%	50%	55%
Freeze Dates	25%	17%	14%	36%	27%
Tasks	63%	50%	64%	71%	82%
Task Dependencies	40%	33%	21%	36%	36%
Test schedules	54%	50%	36%	57%	45%
Resources	51%	83%	36%	57%	64%
Costs	60%	83%	71%	64%	91%
Scope	43%	83%	64%	64%	64%
Bill of materials	68%	50%	64%	57%	64%
Assembly	49%	33%	43%	43%	27%
Quality	52%	50%	57%	79%	45%
Risk Management	37%	17%	50%	43%	36%
Manufacturing	40%	50%	86%	29%	55%
Sales	19%	67%	29%	7%	18%
Advertising	6%	17%	21%	0%	9%
Product	35%	83%	50%	50%	55%
Design	71%	67%	57%	71%	36%
Revenue	19%	50%	36%	14%	18%
Pricing	24%	67%	36%	29%	55%
Profit	17%	33%	21%	29%	27%
Distribution	10%	33%	36%	0%	18%
Activities	25%	67%	21%	7%	64%
Process	27%	50%	50%	64%	55%
Communication	30%	33%	21%	42%	45%
Other	5%	0%	0%	7%	0%

Understanding the complexity of multiple plans used on multiple projects, for the average design project stakeholder, it is worthwhile to examine the plans that are produced in more detail. The information that is actually being managed by the plans created is examined here to analyze how it may contribute to the complexity of the planning activity. It begins by considering what planning content project stakeholders are actually interested in.

Table 5 indicates the percentage of actual respondents who indicated that they manage that specific content item in at least one plan that they use. The findings verify the multitude of content that is actually referenced by project stakeholders for a typical product design project.

While there are some affinities that would be expected based on functional responsibility, such as product for the Product Managers and manufacturing for Manufacturers, these results suggests that the content that is actually managed by the project stakeholders is varied and very much influenced by specific responsibility and personal preference. It also indicates that the breadth of information managed by all design project stakeholders is quite large.
Based on the findings it can be reasonably confirmed that, while variation does exist between different functional areas, the complexity of the individual planning activity is consistent for all project stakeholders involved with the complex product design process. The use of multiple plans and the wide variation in content managed seemingly suggests that project stakeholders use different plans to manage the various content of their interest for a given project. However, while it is true that the managed content is varied between project stakeholders the conjecture that individual stakeholders use different plans to manage different content does not prove true when considered more closely. In fact, additional scrutiny (data not shown) indicated that many respondents that use multiple plans for a given project actually track the desired content item in more than one plan they use.

4.4 Plan dependencies and shared use

The above findings consider the complex product design process planning activity from the individual project stakeholders. However, most project stakeholders do not conduct their individual planning activity in a vacuum. The complex product design process is most often a highly communicative activity that involves input from multiple individuals and work teams transcending a multitude of functional responsibilities. In his paper describing the Design/Manufacturing interface, Adler states that as the phases of work unfold within a time bound project, departments typically experience different degrees and types of interdependence [Adler 1995]. As such, even from the perspective of a single project, the planning system associated with the product design process must enable the exchange of information between the multiple sub-systems it is comprised of and their respective environments. In this instance, the environment includes, in part, the different project teams, functional entities and employee levels with same project responsibilities. Each of these entities also have external environmental influences such as external direction like government regulation, for instance, that may impact the project and thus the planning activity associated with it. Much has been written suggesting that this interdependency requirement is often a source of project difficulty. In examining designers across nine corporations, Curtis et al. stated that one of the biggest problems was communication and coordination breakdowns [Curtis et al. 1988]. Tan et al. cited insufficient communication phases between similar or different functional responsibilities as a reason for long development cycles [Tan et al. 1996]. A distinction should be made between communication and the exchange of information in that while highly complementary they are not necessarily the same thing. Adler describes the concept of coordination mechanisms and cites Thompson [1967] for including "plans and schedules" as one of the four coordination mechanism techniques that can be used to engage interaction between project stakeholders. [Adler 1995] As such, the role of the planning activity to affect communication and information exchange is examined here.
Table 6 indicates the percentage of plans used by those respondents who indicated they interact with other project stakeholders that are actually shared with those they interact with. The figures on the bottom side of the diagonal indicate the percentage of plans that members of those functional groups stated they shared with the functional groups going across the top of the table. Similarly, the figures on the topside of the diagonal indicate the percentage of plans members from the functional groups going across the top of the table indicated they shared with members from the functional groups going down the left side of the table. The "other" group only goes in one direction because the respondents in that group are too varied to decipher a reading coming from the other groups.

Table 6. Percentage of plans shared with groups interacted with

	Engineering	Manufacturing	Marketing	Project Management	Others
Engineering		54%	49%	48%	57%
Manufacturing	66%		58%	50%	63%
Marketing	23%	10%		54%	54%
Project Management	63%	52%	39%		64%
Others	X	X	X	X	

The activity of sharing plans is not symmetrical between functional responsibilities, which is clearly indicated by the results. This result suggests that plans are definitely used for the exchange of information but a significant amount of information exchange occurs outside the planning activity. This indicates a somewhat mixed message regarding planning activity complexity. From one perspective it suggest that changes to plans that are shared can be more easily communicated as the changes are immediately identifiable to all plan users. On the other hand, it suggest that changes to these shared plans need to be individually propagated to the plans that are not shared. Based on the findings discussed above, the logic here is that many project stakeholders manage the same content in multiple plans they use. Additionally, it also indicates that there is not a clear way to propagate changes made to non shared plans to other plans that may need to be cognizant of that change.

Table 7. Plans used dependencies on other plans

	Engineering	Product Management	Manufacturing	Other	Project Management
No dependencies	31%	23%	23%	25%	33%
My work team	37%	35%	38%	42%	55%
My subordinates	10%	12%	22%	17%	25%
My superiors	21%	19%	16%	28%	28%
Engineering teams	30%	15%	33%	30%	53%
Marketing teams	6%	8%	22%	13%	18%
Manufacturing teams	15%	8%	38%	22%	23%
Operations	10%	15%	16%	25%	45%
Project Management	19%	27%	17%	22%	35%
Product Management	10%	19%	28%	18%	20%
Program Management	4%	0%	11%	18%	18%
Suppliers	15%	19%	20%	20%	33%
Customers	17%	23%	23%	10%	35%
Software teams	2%	8%	8%	18%	20%
Finance	3%	0%	22%	7%	20%
Outsourced Personnel	2%	0%	8%	23%	13%
Others	2%	8%	2%	3%	8%

Considering that a significant number of plans that are created are not shared suggest that many plans are created for individual use. This notion is supp.orted by the above finding showing the percentage of plans that are created by the individual project stakeholders themselves. However this begs the question of whether the information that is included in these self-created plans is coming from elsewhere. It is logical that some of it is likely coming from the plans that are shared from other project stakeholders. However, it must be asked if these plans have dependencies on other non-shared plans. Table 7 indicates the percentage of plans cited that have dependencies on plans produced by other functional areas for the different functional areas. Each functional group stated that app.roximately one quarter of the plans cited have no dependencies. Each functional group also suggested that only a minimal amount of the plans they use have dependencies on plans produced by project stakeholders from other functional disciplines.

In addition, the plans used were more likely to have dependencies on plans produced by members of their immediate work team.
These dependency findings add credibility to the previous findings suggesting that the planning activity is quite insular to the particular functional area and individual project stakeholder. This again suggests a mixed result regarding planning activity complexity. While limited, the results do indicate instances of interdependencies between plans used by different project stakeholders. This implies a need to coordinate dependent plans when product change occurs. At first glance the minimal amount of dependencies between plans suggested by the respondents would seemingly limit this coordination requirement thus minimizing this complexity. However, the above findings suggest that the content managed by plans used between project stakeholders from different functional areas is not unique to that functional area. From this perspective it must be asked how this project related information is coordinated between functional areas and whether a more robust planning system could assist in accomplishing this objective.

4.5 Plan changes

One of the specific concerns about understanding the interdependency of the plans used is related to the distribution of project change information to those who require it. Such change is not uncommon in product design projects and one would logically speculate that change information is propagated to project stakeholders via the planning system. These findings indicate that this is not necessarily the case. Given the frequency that the respondents indicated plans are changed would seemingly supp.ort a planning system that is more robust in automatically disseminating information to all project stakeholders.

Table 8. Plan change frequency

	Engineering	Product Management	Manufacturing	Other	Project Management
Daily	12%	4%	5%	15%	19%
Weekly	37%	15%	31%	25%	23%
Monthly	22%	19%	25%	22%	16%
Quarterly	13%	23%	25%	7%	12%
Semi-annually	3%	4%	3%	7%	7%
Anually	6%	19%	5%	10%	2%
Never	7%	15%	6%	10%	21%

Table 8 indicates the frequency of plan changes as indicated by each functional group. With the exception of the Product Management group, all groups indicate that plans are changed on a fairly regular basis with a majority of plans being updated within a monthly or shorter time frame. The high percentage of plans that are never changed, as indicated by the project management group, seemed suspicious but on closer observance it was determined that they were early project descriptions such as project charters and requirements or supp.lier related information such as technical descriptions.
This complexity is somewhat magnified when considering how plans are updated. Table 9 indicates how plans are updated for each functional group. The table indicates that a significant majority of plans are updated manually. The manual factor becomes even more predominant when it is considered that the plans that are semi-automatically updated have a manual updating component.

Table 9. How plans are updated

	Engineering	Product Management	Manufacturing	Other	Project Management
Automatically	2%	0%	13%	10%	5%
Semi-automatically	17%	12%	13%	30%	12%
Manually	74%	88%	73%	48%	72%
Do not know	7%	0%	2%	7%	12%

5. Conclusion

This paper presents some of the findings generated when the survey tool PMAST was app.lied to a general population with responsibilities for the product design process. A close inspection of the product design planning activity for the individual stakeholder identifies a complex planning system that consists of the aggregated contribution of each of the individual project stakeholders involved. Most often this complexity begins with the individual stakeholders themselves. The findings offered insight about the planning activity indicating a planning system that is quite complex despite being insular in nature. This complexity is consistent between functional areas and characterized by the following:

- Beginning with the individual project stakeholder, the planning activity is characterized by involvement in multiple simultaneous projects and the use of multiple unique plans to manage each project containing a multitude of diverse content information.
- Contributing to the complexity is the breath of content that is managed and the number of plans that content is managed in.
- The individual complexity is exacerbated by a requirement to interact with other design project stakeholders including the immediate work team, other teams within the same functional discipline or individuals and teams from other functional responsibilities.
- A majority of plans are updated manually on a fairly frequent basis of one month or shorter time frame.

This survey focused on new product development and the general app.lication of the planning activity by individuals with responsibilities in the design process. Specific consideration of planning system maturity, project management methodology, degree of product complexity and direct comparison to other types of process planning activity is not made and as such, suggested as potential areas of further research and future work. However, the results do verify the managed chaos of the product design planning activity that is perceived by many individuals. Acknowledging the difficulty of stating factual information for a general population, there are clearly reasonable observations that can be made from the findings presented here. App.lying PMAST to the general population has demonstrated its value in generating the necessary data to conduct a thorough analysis of the planning activity for a specific population. In this instance PMAST was app.lied to a general population which enabled insight of the complex product design process planning practice. It is suggested that a perhaps more valuable app.lication of PMAST is to a specific organization or project where thorough assessment can be made for a unique closed community resulting in the compilation of targeted recommendations to improve the planning system in place or maximize the value of the planning system that is to be implemented.

References

Ackoff, R. L., "A Concept of Corporate Planning", Long Range Planning, Vol.3, No.1, 1970, pp. 2-8.

Adler, P. S., "Interdepartmental Interdependence and Coordination: The case of the Design/Manufacturing Interface", Organizational Science, Vol.6, No.2, 1995, pp. 147-167.

Allmendinger, P., "Towards a Post-Positivist Typology of Planning Theory", Planning Theory, Vol.1, No.1, 2002, pp. 77-99.

Curtis, B., Krasner, H., Iscoe, N., "A field study of the software design process for large systems", Communications of the ACM, Vol.31, 1988, pp. 1268-1287.

Eppinger, S. D., Salminen, V., "Patterns of Product development Interaction", International Conference on Engineering Design, ICED'01, Glasgow, UK, 2001.

Fowler, F. J., "Improving Survey Questions: Design and Evaluation", Thousand Oaks, CA, SAGE Publications, Inc., 1995.

Galloway, T. D., Mahayni, R. G., "Planning Theory in Retrospect: The Process of Paradigm Change", Journal of the American Planning Association, Vol.43, No.1, pp. 62-71.

Hayes-Roth, B., Hayes-Roth, F., Lindemann, U., "A Cognitive Model of Planning", Cognitive Science, Vol.3, 1979, pp. 275-310.

Kast, F. E., Rosenzweig, J. E., "Contingency Views of Organization and Management", Chicago, IL, Science Research Associates, Inc., 1973.

Lindemann, U., "Methodische Entwicklung Technischer Produkte", Berlin, Springer, 2007.

Maier, A. M., Eckert, C. M., Clarkson, P. J., "A Meta-Model for Communication in Engineering Design", CoDesign: International Journal of CoCreation in Design and the Arts, Vol.1, No.4, 2005, pp. 243-254.

Project Management Institute, "A Guide to the project management Body of Knowledge (PMBOK) - Fifth Edition", PMI, Inc., Newton Square, PA, United States, 2013.

Rittel, H. W. J., Webber, M. M., "Planning Problems are Wicked Problems", Developments in Design Methodology, Cross, N. (ed.), New York, John Wiley & Sons, 1984, pp. 155-169.

Robson, C., "Real World Research", Oxford, Blackwell Publishing, 2002.

Roelofsen, J., Baumberger, C., Lindemann, U., "An Approach Towards Situation Specific Planning of Design Processes", International Conference on Engineering Design (ICED'07), Paris, France, 2007.

Tan, G. W., Hayes, C. C., Shaw, M., "An Intelligent-Agent Framework for Concurrent Product design and Planning", IEEE Transactions on Engineering Management, Vol.43, No.3, 1996, pp. 297-306.

Thompson, J. D., "Organizations in Action", New York, NY, McGraw-Hill, 1967.

Turner, J. R., Speiser, A., "Programme management and its information systems requirements", International Journal of Project Management, Vol.10, No.4, 1992, pp. 192-206.

Waddington, H., "Types of Survey Questions", Encyclopedia of Educational Technology, Hoffman, B. (ed.), San Diego State University, San Diego, CA, 2000.

Walonick, D. S., "Survival Statistics", Bloomington, MN, StatPac, Inc, 2004.

Webber, M. M., "The prospects for policies planning", New York, NY, Basic Books, 1963.

Weber, M., "The Theory of Social and Economic Organization", translated by Henderson, A.M., Parsons, T., New York, NY, The Free Press.

Wynn, D. C., Eckert, C. M., Clarkson, P. J., "Planning business processes in product development organisations", Workshop on Requirements Engineering for Business Process Support (REBPS'03), Klagenfurt/Velden, Austria, 2003.

Wynn, D. C., Clarkson, P. J., "Design Project Planning, Monitoring and Re-planning Through Process Simulation", In International Conference on Engineering Design, ICED'09, Stanford University, Stanford, CA, 2009.

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