COMMUNICATION AND DESIGN PROCESS PLANNING: INITIAL INSIGHTS FROM LITERATURE AND INDUSTRY INTERVIEWS

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ABSTRACT

There is a complementary and bi-directional relationship between communication among design process participants and the planning activity in design. However, while often implied, this relationship is rarely discussed directly in the literature. This paper reports on the first year of a PhD research project to explore this relationship through an empirical study of engineering industry. We discuss the relationship between design planning and communication as revealed in the literature. This is supported by seven interviews with designers and managers in a range of companies and market sectors, between 1 and 3 hours in duration. The paper highlights the reciprocal relationship between how communication enhances the planning activity and how the planning activity enables communication. We discuss further work to explore this area through a survey to investigate how planning practice is conducted in industry. By better understanding the relationship between planning and communication in design, we hope to identify new directions for research into tools and methodologies to improve planning practice in industry.

Keywords: Design Process Planning, Communication

1 INTRODUCTION

Effective planning of complex product design processes is often presented as critical for the timely delivery of a design project. However in contrast to some other aspects of design organisation and management, planning has been given relatively little detailed attention in the design literature. Much of the recent research on this topic has been written from the perspective of how the participants in the product design and development process can come together most efficiently and effectively to ensure the best final product can go to market and compete effectively. A significant body of literature has proposed tools and methodologies to support communication between the various agents involved in the product design process. While all these authors allude to the importance of planning when describing these tools and methodologies, few discuss in detail the complementary relationship between communication and the planning activity.

This paper reports on findings from the first year of a three year PhD project undertaken to analyse this relationship. We explore what has been written regarding the relationship between communication and the planning activity in the areas of systematic design methodology, design planning and design planning practice. Interviews were conducted in a range of companies and industries to further explore the conclusions drawn from the literature, and to explore how design planning is actually practiced in industry and how this is related to communication.

The paper proceeds as follows. Section 2 discusses planning in the design and development literature, reviews models specifically focusing on planning, and briefly outlines literature regarding communication in the design process and the relationship between communication and planning. Section 3 discusses the industry interviews and their findings. Section 4 presents insights gained, to date, and presents a model which indicates the role of communication in design planning. Section 5 discusses further work being undertaken to develop this research through a survey which has been developed to explore some of the areas of interest. Section 6 concludes.

2 PLANNING IN THE DESIGN LITERATURE

This section discusses how planning activity has been presented in the design literature and highlights the important role of communication in the design process. The section concludes with a perspective on how planning and the relationship between planning activity and communication have been presented in the literature and highlights the scope for further research on this topic.

2.1 Overview of the design and development literature

Many authors have proposed models describing or prescribing the engineering design process. Perhaps one of the most widely known and cited is that proposed by Pahl and Beitz [1] in their discussion of design from a psychological, systematic and organisational perspective. The organisational perspective is captured in their representation of the life cycle of a product where "Design/Development" represents a significant and arguably the most important link in the product lifecycle. Focusing more specifically on this "Design/Development" process, Pahl and Beitz present a systematic approach that comprises the four phases of planning and clarifying the task, conceptual design, embodiment design and detail design. Ulrich and Eppinger [2] propose a similar systematic stage based approach, including the additional phases of testing, refinement and production ramp-up which occur beyond the detail design phase represented in the Pahl and Beitz model [1]. Based on the design practice observed in industry, French proposed a similar four-phase design model as early as 1971 [3]. Since then many others have proposed similar models that essentially comprise a linear sequence of phases that start with a perceived need and conclude with a detailed description of a particular product [4 - 10]. Others suggest that these linear stage-gate models are too rigid in defining the beginning and ending of a particular stage, since stages are often dependent on each other. Cooper proposed a third generation new product process, offering the advantages over previous models she deemed the four fundamental F's: fluidity, fuzzy gates, focused and flexible [11]. Pugh embraced the broader perspective of product design when he wrote that industry is concerned with "total design" which he described as "the systematic activity necessary, from the identification of the market/user need, to the selling of the successful product to satisfy that need – an activity that encompasses product, process, people and organisation" [6].

Expanding beyond the realm of the design process it is worthwhile to review what has been written regarding product design. Ballard recognises this interrelationship between these activities when he defines "concurrent engineering" as the intent to integrate the teams and production of product and process design, which he suggests are typically addressed independently [12]. However, beyond describing them both as types of production which require production planning and control, he does not explore how the planning activity contributes to the communication between functional areas or work teams. In a related domain, many authors have proposed models for product planning with that proposed by Booz, Allen and Hamilton being one of the most recognisable [13]. They describe a six-stage process that includes; (1) Exploration, (2) Screening, (3) Business Analysis, (4) Development, (5) Testing, and (6) Commercialization. Much has been written referencing the Booz, Allen and Hamilton model but like that of the more specific design process models, while highly cognisant of the planning activity there has been little reference to the relationship between communication and the planning activity.

2.2 Planning in the design and development literature

Pahl and Beitz suggest that the Planning and Clarifying the Task phase results in a requirements list which then forms the basis for the subsequent design phases [1]. They further discuss the idea of "procedural plans" which they refer to as "operational guidelines for action" that define the working steps for progressing the design process. Ulrich and Eppinger write that planning the design process involves scheduling the project tasks and determining the resource requirements [2]. They further suggest that the project plan is laid out during the development phase and continues to evolve throughout the design process. Both sets of authors indicate the requirement for planning activity to be conducted within the engineering design function itself but do not emphasise the need to consider the broader design project, which is influenced by many factors external to the engineering design function is not emphasised. However, since these external influences are widely recognised as significant in all design projects, design planning and management activity should consider the multiple functions involved. In turn this suggests the importance of communication between design teams, both within and between functional areas, in planning.

The model presented by Hales [8] indicates that the "resolution" and "viewpoint" taken of a project could have significant impact on the planning activity. 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. Hales references Rodwell [14] when he applies four characteristics to projects including magnitude, complexity, novelty and production quantity and suggests that each can be viewed as a scale representing a range of extremes having a major influence on the way a project is managed depending on where the project falls within that range. While authors such as Pugh and Hales embrace the need to take a broader perspective of a design project, they do not analyse in detail how this influences the planning activity of a project or how planning requires communication between different participants.

Other authors take a more detailed perspective of the planning activity. For instance, Robertson and Ulrich discuss the relationship of the three "information management tools" associated with the platform planning process they refer to as "Product Plan", "Differential Plan" and "Commonality Plan" [15]. In presenting their conceptual framework on integrating design with manufacturing and marketing Fitzsimmons et al. allude to the importance of recognising the interrelationships that exist between design, manufacturing and marketing as an enabler of flexibility in planning [16].

Much of the literature written about the broader subject of product planning also recognises the interrelationship of functional areas and work teams. In their study of new product management practices of small technology firms, Boag and Rinholm [17] found that respondents suggested that new product development policies "define the coordination between a number of people and departments – the expectations of who should be doing what, after whom", which clearly suggests a communication requirement. They propose six product development methods and their finding suggests a strong relationship between a robust planning activity and the number of methods used. However they do not discuss the value of using the planning activity as a communication tool between the people or departments involved. In their study of new product planning principles versus practice, Feldman and Page suggest that product planning is a "people process" which is inherently multilayered, cross-functional and interdisciplinary [18]. They refer to Booz, Allen and Hamilton [19] when stating that strategic planning establishes the basic direction of the firm, and that a cornerstone of the strategic planning process is the derivation of new product plans to meet long range challenges. However, they do not analyse the relationship between the planning activity and the implied communication requirement. Wind argues that product planning should be integrated with the planning of other business functions but does not really propose how this would be best accomplished [20]. From the perspective of Design Planning Teams, Klein and Miller suggest that a plan's function is to "Develop a shared situation awareness", suggesting that planning supports communication between team members. While recognising the relationship between plans and communication they do not explore it in detail from the perspective of the design process or of product development [21].

In summary, while many authors imply a significant role for communication in the planning activity, most do not analyse the relationship in depth, particularly when considering design in particular.

2.3 Literature proposing models of design planning

The relationship between planning activity and communication is also not typically highlighted in models of design planning. Roelofsen et al. expressed uncertainty as to whether the business planning models could be used in design planning, due mainly to the novel, unstructured and not fully-comprehended nature of the product design process [22]. It is these inherent characteristics of the design process that magnify the importance of communication between agents of interest in order to develop plans.

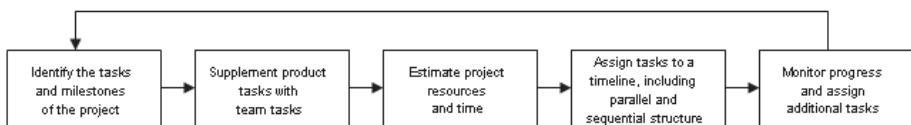Otto and Wood proposed the planning model shown in Figure 1 [23].

Figure 1. Otto & Wood's Planning Model [23]

While this model is similar to the planning methods suggested by authors of stage-gate based design process models such as Pahl and Beitz [1] and Ulrich and Eppinger [2], it also does not highlight the dynamic nature, complexity and internal and external variables involved with the product design process or the importance of communication in the design process planning activity. Building on the sentiment that the design process strongly depends on situational conditions, Roelofsen et al. propose the "situational planning model" [22]. This model builds on the concept suggested by Maffin that different levels of process decomposition should be considered, supporting the appropriate planning detail and based on the analysis of the specific design situation [22] [24]. While highly detailed and very cognisant of the complexity of the design process, this model does not specifically address the role of communication in the planning activity of the design project. Wynn et al. [25] present a model which decomposes planning into the activities of planning, monitoring and re-planning. They draw upon Roelofsen's model to argue that a key difficulty in these activities is reconciling an understanding of the project in terms of performance-level objectives, such as cost, with that in terms of plan-level objectives, such as activities. This implies communication among the stakeholders who consider these different levels. However, they do not discuss how such reasoning is conducted in practice. Nadler presents a "timeline theory of planning and design" which highlights the importance of involving people to "maintain continual contact between the P&D [planning and design] and client worlds but does not elaborate on how the planning activity can be used as a communication tool to this effect [26]. Looking at the broader realm of product design and development, Wind describes several of what he deems "product development systems" while suggesting that no one system is applicable to multiple companies [20]. Despite the variations, all the systems referenced have many communication implications between functional areas and work teams involved with the product development process. However, like that of the more specific engineering design process they typically lack detailed discussion regarding the relationship between communication and the planning activity. Wind himself argues that a product development system should provide an operational link between the relevant business functions but does not elaborate on how the planning activity contributes to accomplishing this [20].

2.4 Relationship between communication and planning in the literature

The Oxford English dictionary describes communication as "the imparting, conveying, or exchange of ideas, knowledge, information, etc. (whether by speech, writing, or signs)" [27]. In practice this definition may be simplistic when considering the intricate role communication plays in the complex product design process. In developing her grid-based assessment of communication in engineering design, Maier described communication theory as rich but disparate while citing several authors that identified as many as two hundred distinct variations of communication theory [28]. Perhaps this explains why much of which has been written takes on a very defined scope addressing a particular aspect of the communication puzzle. In discussing their five approaches to accelerate New Product Development, Millison et al. cite "continuous, open and timely communication" as a requirement of implementation but rarely discuss how the approaches discussed are enabled by or affect the planning activity [29]. De Vreede and Briggs present a Collaboration Engineering design approach that implicitly implies planning activity, but only actually include "make a plan" as one of the stages of the "goal attainment model" associated with the "Process Layer" of the group interaction model [30]. When discussing concurrent engineering, Tan et al. [31] cite insufficient communication phases involving similar or different functional responsibilities as a reason for long development cycles. To address such constraints they have defined a partially automated model that utilises conflict resolution techniques and design improvement suggestions to refine the product design and process plan generation to ensure manufacturability. However, beyond suggesting a result of using the model that includes process plan generation they do not extensively elaborate on the overall product design planning activity [31]. Sonnenwald deemed communication a "fundamental component" of the design process and identified thirteen communication roles associated with such an effort [32]. While recognising the value of communication she did not really elaborate how the planning activity may contribute to or inhibit these communication roles. In their evaluation of "Communicative Planning", Faludi and Altes do address the relationship between planning and communication but not specifically from the perspective of the design process [33]. They argue that "the purpose of planning is to improve the quality of decisions in terms of whether their justifications take account of the wider field of choice" by enabling communication between the plan-maker and the decision-maker [33]. Their

argument adds much to the communication and planning relationship discussion, and one of the key objectives of this research is to analyse the same relationship but in the specific context of the engineering design process.

2.5 Summary

To summarise, when discussing design processes and methodologies, many authors allude to the planning activity but do not analyse it in detail. Likewise, the role of communication in design project planning is often implied but usually not discussed in detail. There is recognition of the importance of each in the design process, but the focus of most publications is on the particular tool or methodology being discussed rather than on how planning and communication are related.

Drawing on this analysis of the literature, we concluded that there is therefore scope to further research the relationship between planning and communication in design from three complementary perspectives. Firstly, to identify how communication between different participants is required in order to plan effectively and how this could be supported. Secondly, to identify the role of the planning process, i.e. the act of making plans, in assisting communication between process participants about project goals and resolving co-ordination issues. Thirdly, the role of planning documents as objects which facilitate communication about the design process, its composition, organisation and objectives. Exploring these aspects could provide insights into how design planning could be better supported.

3 INDUSTRY INTERVIEWS

Seven industry interviews were conducted to better understand how design planning activity is conducted in practice and to further explore the role that communication plays in planning activity as approached in industry. The objective was to generate feedback from a cross-section of engineering industry. Seven semi-structured interviews of between 1 and 3 hours in duration were therefore undertaken with engineering and management personnel from two US telecom companies, two divisions in a UK aerospace manufacturer, a UK cellular telephone manufacturer, and two large EU automotive manufacturers. Table 1 gives a description of the companies, interview format and personnel interviewed for each interview. Following sub-sections describe the research methodology and summarise the initial findings generated.

Table 1. Summary of interviews conducted

Industry	Product	Company size	Interview format	Interview duration	Description
Aerospace	Composite Aircraft Structures	>40,000	Telephone	1 Hour	Interviewed the Technology Manager of their Aerospace Division.
Automotive	Automotive parts and sub-systems	>250,000	Telephone	1 Hour	Interviewed 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	Interviewed 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	Interviewed a Design Engineer and Program Manager for the Aerospace division.
Telecom	Integrated Voice and Multi-media switches	< 300	In Person	3 Hours	Interviewed the Directors of Project Management and Software Engineering.
Telecom	Contact Centre Analytic hardware / software system	< 100	Telephone	1 Hour	Interviewed the Product Manager for their most recent product introduction.
Telecom	Mobile Telephone	>60,000	In Person	2 Hours	Interviewed a Design Engineer for the UK mobile phone division.

3.1 Interview methodology

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

- Tell me about yourself and your responsibilities.
- 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.

Under these high-level headings, the subject of communication and its role in the planning activity was incorporated into the line of questioning. 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, including communication.

3.2 Findings from the interviews

The following main conclusions were drawn from analysis of the interview notes and transcripts:

- A common planning activity structure could be identified, although details varied. For example the number and type of planning documents created or the amount of communication that takes place between collaborating teams varied from project to project.
- There was a distinct linear stage-gate based design model forming the basis of the planning activity in all organisations, 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 exists 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 occur in isolation until conflict arises. The intensity of this communication is usually dependent on the progress along the linear stages often becoming more magnified as the project gets closer to a hand-off between the functional areas in question.
- External factors, both generated from outside and within the company, appeared to very much factor into 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. Again, interviewees appeared to view this as a significant issue.
- 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. These documents are most often created in isolation.
- The tools used to create the planning documents utilised were often off-the-shelf tools such as the Microsoft suite of management tools. Other tools which could potentially be used to support coordination of planning activity, such as document management systems, did not appear to be used in this way.

In summary, considering the uniqueness of the companies interviewed in terms of size, location and sector, there were still many characteristics that their respective planning activities shared. Adhering to the findings of Eckert and Clarkson [34] the planning practice was found to be departmentalised or even individualised in many cases. In general the findings of the interviews supported the observations of Eckert and Clarkson [34] made in four industrial case studies, in which the organisations studied had many plans at the same time with no umbrella master plan that covered all aspects of the project in detail. They further observed that everybody planned a particular aspect of a project to satisfy their individual needs.

One of the interviewees described a very thorough and documented planning methodology in their company, before saying that it was never used in practice. The general importance of communication (for instance, between different groups) in coordinating the design process was mentioned by all the interviewees, however, the processes for communication as part of the planning activity appeared very informal.

4 DISCUSSION

4.1 Towards a descriptive model of design planning

As part of this research project we aim to develop a detailed descriptive model of the design planning activity as conducted in industry. Figure 2 presents an outline of such a model, summarising the characteristics of design process planning identified through the literature and interviews that have taken place with organisations to date. The model, while presented from the perspective of the engineering function, is intended to highlight important aspects of the communication requirement embedded in the planning activity of the design process by identifying where communication needs to occur. It identifies the need for communication within the same functional area in each stage of the design project. It also highlights the need for communication between functional areas demonstrating the intensity of that communication in relevance to planned handoffs. It points out the use of gates as a communication tool between stages and suggests the difficulties incurred when that communication breaks down. Finally it embeds the design project within the environment of internal and external forces suggesting that changes generated from these forces must be communicated properly to the design project participants. Due to the iterative nature of the design process communication between design teams working within the same stage is critical. From the perspective of the overall project the effectiveness of this aspect of communication should possibly be the easiest to ensure – but our findings so far suggest that it is often informal and somewhat unstructured. Communication between stages is also critical and comes in two distinct scenarios. Handoff between stages within the same functional area is typically managed using go-no go gate criteria. Handoffs between functional areas are also managed by go-no go gate criteria but the consequences of mistakes tend to be much more serious to the ultimate successful delivery of the product. While the lists of criteria themselves are somewhat formal, the communication around the list, like that previously mentioned, is quite informal. Communication between functional areas is likewise very critical. Our findings suggest that this communication intensifies greatly as a handoff between functional areas becomes more imminent but like the others it to tends to be unstructured and somewhat informal. Finally, design projects are embedded in the larger corporate environment which in turn is embedded in the even larger external environment. Both very often subject the project to specific demands that must be effectively communicated to all the agents of interest working on it.
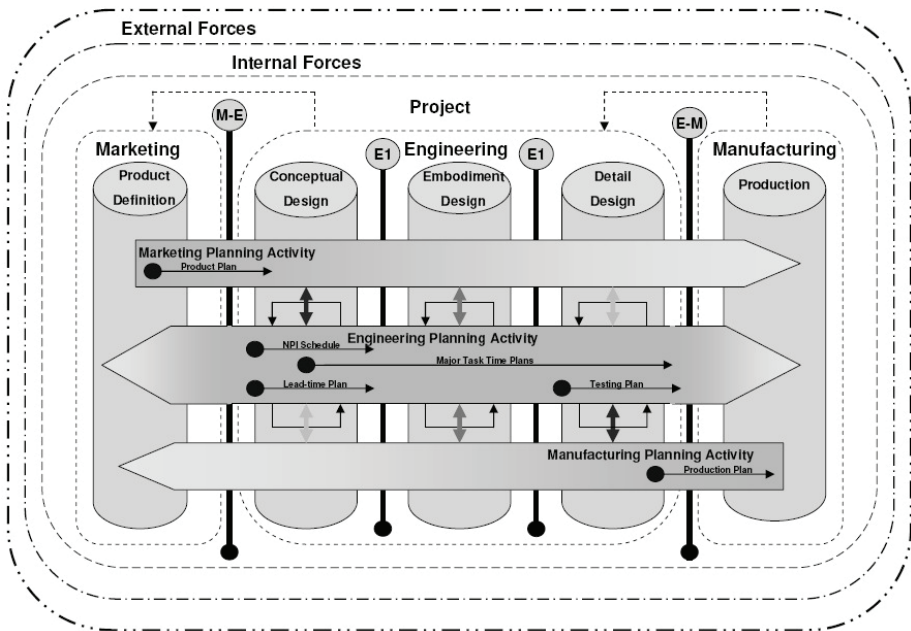

Figure 2. High-level descriptive model of design planning

4.2 Initial insights into opportunities to support design planning

From the analysis of interviews, which is described above, and the literature, the following initial insights were generated into communication-oriented opportunities to better support design planning:

- The planning methodology adopted must be flexible enough to adjust to the natural variations that occur between projects. This flexibility needs to extend to policy regarding communication between the various agents of interest.
- The stage-gate design model on which the planning model is based suggests the need for communication between design stages before the process can progress. This interaction should be captured within the planning activity to maximise the efficiency of the communication and ensure that it is available for future reference.
- Communication is essential between functional areas before conflict actually arises. While conflict between functional areas is not completely avoidable it is important to minimise it by recognising potential issues of conflict as early in the process as possible. This suggests that communication between functional areas may be necessary earlier and more frequently in the design process. A potential way of achieving this is to implement a more interactive and automatic planning activity between functional areas.
- External factors affecting the process design must be communicated to all relevant agents of interest and properly reflected in the planning activity for efficient communication and proper capture for future reference.
- The iterative nature of complex product design means that the planning process must be flexible enough to recognise the probable occurrence of product iteration and adapt accordingly both within a design stage and between design stages to ensure the communication of such iterations is efficient and effective.
- The large number of isolated plans created indicates the need for a collaborative planning activity that is communicated properly to all agents of interest involved with the process design project.

While many of these proposals seem quite obvious at first glance, our initial findings suggest that they are not typically practiced in a systematic and structured manner. Further research is needed to further develop these ideas and evaluate whether they could enhance the effectiveness of planning practice.

5 FUTURE RESEARCH

This paper has reported on findings drawn from a relatively small number of industry interviews. In order to reach a much larger audience to support and detail these findings a survey has been designed, and in its initial form can be found at www.designplanningsurvey.com. The survey content is designed to enable the analysed results to define clear patterns around the overall planning model followed, planning activities conducted and planning tools used. Embedded in the survey are many questions purposely included to decipher the relationship of communication and the planning activity as it is currently practiced. Information generated from the interviews conducted was used to identify the main categories of questioning and develop the series of questions addressing each category. A beta version of the survey was tested amongst a select group of engineering professionals for further refinement before final distribution. Figure 3 shows several of the main survey screens.

The sections of the survey are designed to elicit a comprehensive story of the individual respondents' understanding of the planning activity they use. Embedded in that story is the role of communication in the overall planning activity. Table 2 shows the sections of the survey, each of which includes blocks of questions pertinent to that topic.

It is our expectation that combining the survey results across all respondents will help establish more firmly the relationship between planning and communication and how this is influenced by characteristics such as functional area, level of management, type of product, business sector, organisational size etc. In addition, ongoing with this survey development, we are conducting a more comprehensive study of the literature to develop a conceptual framework for analysing the results.

Figure 3. Screens in the design planning survey

Table 2. Sections in the survey and their objectives

Section	Objectives
Product Designed	This section of the survey is designed to create an understanding of the actual characteristics of the product being designed.
Plans Used	The Plans Used section identifies the functional areas of the organisation that are involved with the planning activity and the most important plans utilised by the respondent. It will indicate whether plans are shared or used in isolation and suggest potential areas where communication is needed.
Planning Dependencies	This section builds on the identification of the functional areas of the organisation that conduct planning activity for process design and what determines their dependencies amongst each other. It will determine whether different functional areas and/or work teams created plans that are dependent or should be dependent on each other, which suggests the need for communication.
Plan Creation / Maintenance	This section asks when plans are created during the design process and when are they actually used. It also addresses the maintenance aspect of the plans being used regarding how often they are actually updated and for what reasons. It indicates when and to whom communication of plan maintenance has to take place.
Plan Creator / User	This section asks specific questions related to who the creator and user of the plans used are from both the functional responsibility and management level perspective. It will expand on the determination of where plans are shared or used in isolation by specifically defining who actually uses the plan.
Plan Success	This section identifies several criterion of success from a project perspective related to the plans created and specifically asks the respondent to rate them from a poor to excellent range. It specifically asks how valuable the plans are in the areas of communication, collaboration and conflict resolution from the perspective of those using the plans.
Plan Tools	This section was designed to verify what tools are being used to create the plans that have been identified. In identifying the tools, the respondent will also be asked how satisfied the tools are in meeting their requirements.
Plan Reasoning	This section asks why do respondents use the plans and the tools that they use. A specific objective of this section is to determine if there is a significant pattern of respondents suggesting that they use the plans they use for communication type reasons.
About You	Provides demographics of the respondent.
About Your Company	Provides demographics of the respondents company.
Advanced Methodologies	This section has been included in the survey to gain a better understanding of just how aware industry is of the availability and use of advanced design management methodologies and tools.

6   CONCLUSION

Academic research has recognised, through descriptive writings and the proposal of tools and methodologies, the importance of both planning and communication in the design process. Interviews reported in this paper suggest that this sentiment is concurred by industry. However, the relationship between planning activity and communication in engineering design has not been thoroughly addressed in the theoretical literature or through empirical studies. Much of what has been written implies a complimentary relationship between the two aspects but does not specifically analyse how this relationship manifests in practice. By examining the relationship between communication and the planning activity, from both a literature and empirical perspective, it is our goal to better understand the bi-directional relationship between these activities.

This paper has presented some preliminary conclusions drawn from interviews to explore this relationship. Initial findings suggest that this relationship is typically quite informal in practice, suggesting that the use of the planning activity as a communication tool is often not recognised and perhaps not exploited. There is thus scope for a more extensive study to investigate these issues further. To that effect, we have proposed future research to examine this topic in greater detail with the ultimate goal of identifying opportunities to enhance current practice by ensuring that these two extremely important aspects of the design process are complementary and supportive of each other.

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