Planning Product Design & Development: Resource-Influencing Factors Based on Experience

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Abstract

Time is the universal resource for Product Design and Development (PDD) projects which has a range of factors that influence its length. By sharing their perceptions on such factors, designers can provide insight to those who estimate/schedule. Understanding which factors are most influential may result in improvements in such estimations, offering improved organisational understanding of product development and a perspective to evaluate initial project briefs. This paper examines the factors that influence PDD project length found in literature, comparing them to those considered influential by design teams.

Keywords: Innovation, Product and Service Development, Project Management

Introduction & Background

The universal resource for any design project, product design or otherwise, is time. Common to any project and once it has been used, you cannot create any more. It may be considered possible to buy more time, by hiring more people for a project, yet the reduction of project time per new person added plateaus, as each additional man added to a project will require time to communicate with colleagues (Brooks, 1975). In the design space project time is measured in either person-hours or person-days, with workers recording their efforts using timesheets, informing the billing of clients, although billing may label the time by just the increment, i.e. hours, or weeks, as many agencies will bill for one length of time, but will work for many more, or less. This is especially the case with smaller consultancies and agencies. With such a universal resource, there is undoubtedly a wide range of potential factors which could influence the required time to complete a project. By sharing their perceptions on such factors, design teams can provide insight, informing their management, who are likely making the scheduling decisions. This sharing of tacit knowledge can align such perceptions between groups, bringing them "onto the same page". Understanding highly influential factors of project length may result in project time estimations improvement, offering a means to assess and classify project briefs from the project outset, improving transparency and organisational understanding.

This paper discusses two workshop case studies conducted at UK-based product design engineering consultancies, Design Consultancy A (DCA) and Design Consultancy B (DCB). Each have diverse project portfolios, ranging in both size and subject area. The participants of both studies are Product Design Engineers, Product Designers, or similar.

The writing on what factors influence design project length is varied, from specific parts of the PDD process, such as tooling design, to more generalised discussions of so-called "creative" projects, such as construction, NPD projects, etc. There is limited writing on the such factors from the design consultancy perspective.

Although certain tasks are repeated from project to project, by its very nature, design projects are uncertain. No more so than projects from multi-disciplinary product design, or product design engineering consultancies; where no two projects will ever be the same. This uncertainty is ubiquitous throughout product design (Earl, Johnson and Eckert, 2005), project briefs will have unknown parameters, processes, conditions, etc. and is the cause of critical variation in design projects (Vaagen, Kaut and Wallace, 2017). It is this uncertainty which underscores not only the challenge, but also the need for accurate resource forecasting for design projects as uncertainty leads to variation in tasks and task length and therefore the types and quantities of resources required. Therefore, though an improved understanding of the factors which influence a product design project, that uncertainty can be managed and resources can be more accurately forecasted. The analysis of data is an avenue for understanding such factors, this typically requires bodies of past data, predicated on accurate, homogenous record keeping and analytical software. Yet an organisation and its members' experience, and ability to problem solve will determine the extent to which uncertainty, ambiguity and complexity will be experienced by its design team (Antonsson and Otto, 1995). It is this experience, the tacit knowledge of experts, that can lead to successful design project planning (Andersen, 1996; Bashir and Thomson, 1999; Eckert and Clarkson, 2010).

Bryson and Delbecq propose fifteen "Contextual Variables" which affect project planning: Number of groups involved, Degree of value agreement (Awareness of problem, Priority given to problem, Intensity of concern), Technical difficulty (Comprehension of causation, Sophistication of technology), Time available, Money available, Impact on organizational structure, Impact on resource allocation, Coalition development, Character of lead organization, Character of planning staff, Technical quality of proposal, and Environmental stability (Bryson and Delbecq, 1979).

Xu and Yan propose seven factors as the variable for product design time in a proposed intelligent estimation system: Product Characteristics (Structure, Size, Shape, Added demands), Design Process (Standardization, Process control, Concurrency), Design Condition (Design tools, Management support, Available data), Design Team (Collaboration, Individual experience, Individual skill, Dedicated spirit), Project Complexity (Technical difficulty, Parts amount, Characteristic amount, Uncertainty), Information Process (Capability, Timeliness, Extent) and Motivation (Goal explicitness, Goal congruence, Linked rewards) (Xu and Yan, 2006).

Bryson and Bromiley outline critical factors of projects into three categories: Context, Process and Outcome; each with their own list of factors (Bryson and Bromiley, 1993). The context category has eight factors (Involvement, Planning Staff, Technology, Time available, Impact/Required, Stability, Prior Coalitions, Power), for Process: Communication, Forcing and Compromise; and for Outcome: Success and Learning.

Similarly, Rondinelli, Middleton and Verspoor categorise their factors on project planning into three sections (Socio-economic Environmental (Political and administrative systems, Economic systems, and Organisational Environment), Degree of innovation (Task variety, Task Analysability, Scale of Innovation, degree of deviation of innovation), and Cultural Value (Power distance, Uncertainty avoidance, Individualism-collectivism and role differentiation). (Rondinelli, Middleton and Verspoor, 1989),

Christensen suggests that there are two "variables" which can be used to asses a project: Goal and Technology (Christensen, 1985). A goal can be agreed or not agreed; a technology can be known or unknown. The four potential combinations are referred to as "problem conditions": Programming (Agreed goal, known technology), Bargaining (Not agreed goal, known technology), Experimentation (Agreed goal, unknown technology), and Chaos (not agreed goal, unknown technology). Christensen suggests that these can be used to assess a project, with recommendations for each condition.

Rezania, Baker and Burga outline 23 “Levers of Control (LOC)” which can be considered a comparable term for influential factors (Rezania, Baker and Burga, 2016). These LOC’s focus on the management and organisation of businesses and their teams (communication, culture, progress monitoring, etc.) but include such factors as: project cost, project time, project scope, size and type.

From this sample of literature, the most common factors that influence design time range from the product complexity and project budget, to process controls & tools, and the priorities and motivations of the stakeholders.

Research Questions

This paper will aim to answer the following research questions:

- Do the factors considered to be most influential of PDD project length in literature match those of practicing Product Designers and Product Design Engineers?
- Are there factors that are considered influential in industry which aren’t greatly covered in literature?
- Do the factors considered to be most influential of PDD project length vary between design agencies?

Methodology

This paper examines key factors which influence PDD project length found in literature and compares them with those considered influential by this in. This study takes a case study approach, conducting two workshops with two design consultancies. Case studies were conducted as informal discussions, with the researcher observing and providing occasional conversational prompts. To provide context for the informal discussions, participants from each consultancy were instructed to think about their design process and the tasks commonly accomplished in each stage; Participants were also asked to establish a unit of measurement for project length (i.e. hours, days, etc.), providing further context. Participants were asked to produce a list of all conceivable factors which may influence project length, limited to only what factors could be evaluated from the project outset, as a tool for planning. Participants were instructed to vote for a shortlist of four, or five factors which have the greatest influence over project length, based on the Pareto 80:20. The specific case study methods vary as process improvements were introduced.

Case Study 1 – Design Consultancy A (DCA)

Design Consultancy A (DCA) is a UK-based Product Design Engineering consultancy with experience in developing products in a diverse range of fields. DCA had a team of eight experienced product design engineers participating in this study. Participants were tasked with the following aims: identify key project stages, identify key project resource(s), identify every potential factor that influences previously identified design project resources, and identify key factors from said list.

Process 1 – Identify Key Project Stages

This initial task required the participants to identify the stages, or phases of work found in any design project. By identifying the stages, or phases of work, for any design project early in this process, the participants are provided with context to consider influential factors from. DCA design practice follows the Design Council's Double Diamond (Norman, 2013) with its four stages: Discover, Define, Develop and Deliver; each with their own assigned tasks and sub-tasks. At the time of study, the design team at DCA had just completed an audit of their design activities, and were able to clearly and confidently define each stage and their corresponding tasks.

Process 2 – Identify Key Project Resource(s)

This task required the participants to identify the key resource, or resources, required for any design project. Accompanying any resource identified, the participants also selected a suitable unit of measurement for each resource. This provides context for the participants when considering influencing factors through the perspective of the key project stages. At DCA, time was identified as the only suitable key resource which was ubiquitous throughout every conceivable design project. Although designer workload at DCA is managed in both person-hours and person-days, participants agreed to person-days as the unit of measurement for time, as this is what their clients would be billed for.

Process 3- Identify Every Potential Factor that Influences Design Project Resources

This task required participants to create an exhaustive list of every factor that may have influence of the number of person-days a project would require, both positively (i.e. saving time) and negatively (i.e. wasting time). During the informal discussion and brainstorming session between all the participants, eighteen distinct factors were identified, listed in Table1 in the order they were discussed. This discussion would see individual participants posit a factor, and the remaining participants would discuss openly the merits of the suggestion. On several occasions, one approved suggestion would either provoke a new suggestion, or modify a previously suggested factor. In particular, the discussion of accessibility of clients (a factor suggested early in the process) was sub-divided into *geographic accessibility* and *availability/willingness*, which, in turn, prompted the same sub-division of accessibility of key stakeholders and manufacturers.

Table 1 – Factors for Person-hour influence in Design Projects at DCA

Prior knowledge (Background & Experience)	Testing Complexity
Availability of staff (holidays, other projects, etc.)	Number of key stakeholders
Accessibility of key stakeholders (geographically)	Materials Budget
Accessibility of key stakeholders (availability / willingness)	Regulatory complexity
Accessibility of client (geographically)	Product complexity
Accessibility of client (availability and willingness)	Project Scope
Accessibility of manufacturers (geographically)	Need for subcontractors
Accessibility of manufacturers (availability and willingness)	Equipment availability
Personality & Relationship with clients	Space to work

Process 4- Identify Key Factors from List
Identify the key factors which have the most influence over said resource(s) and rank them in order of perceived level of influence. Considering the 80:20 Pareto ratio, we can consider that the top five factors would be perceived to be the greatest influence over the resources for a given project. Participants then used "sticky dot selection" to decide the top five most influential factors for project time. The use of "sticky dot selection" was not the most successful, as participants took it in turns to cast their "votes". This resulted in those participants who voted later in the workshop, to consider their choices based on both what they considered to be most influential, but also what would be the likely winning factors based the votes that had already been cast. Due to the informal nature of the workshop, those participants who had already casted their votes, attempted to sway the judgement of these latter participants. The researcher insisted that all votes cast were to be based solely on the opinions and experience of the individual participant. This behaviour by the participants has informed specific changes to the method of this study in future case studies. Once the "sticky dot selection" process has been concluded, only seven factors received any votes, shown in Table 2.

Table 2 – Shortlist of Factors for Person-hour influence in Design Projects at DCA

Factor	**Votes**	**Factor**	**Votes**
Product Complexity	5	Materials Budget	2
Project Scope	4	Geographic Accessibility of key stakeholder	2
Regulatory complexity	3	Availability of staff	2
Prior Knowledge	3		

The spread of votes for factors resulted in three factors receiving the same number of votes, 2 each, *Materials budget, Geographic Accessibility of key stakeholders,* and *Availability of staff.* To create a top five list, a second round of votes were cast, with each participant voting for one of the three factors, selecting *Materials budget* as the fifth.

Case Study 2 –Design Consultancy B (DCB)
Design Consultancy B (DCB) is a UK-based Product Design Engineering consultancy with experience in developing products in a diverse range of fields. DCB has a team of six designers and a Studio Manager, all with varied levels of experience in industry and with degrees in Product Design Engineering or Product Design. Participants were tasked with the following aims: identify key project resource(s), identify key project stages, identify every potential factor that influences previously identified design project resources, and identify key factors from said list.

Identify Key Project Resource(s)
Resources were discussed and identified prior to the workshop, with the Studio Manager, it was agreed that the best resource for the case study would be "person-hours" as this matched the resource used when billing clients and how the designers monitored their own time on projects. As with Case Study 1, identifying a specific resource, provides the participants with some context to consider project stages and influencing factors.

Identify Key Project Stages
In addition to Key Project Resources, the Key Project stages were discussed and identified prior to the workshop, as clear stages were already in effect at the consultancy. These stages are based on an adapted form of the Design Council's Double Diamond (Norman, 2013) and included a pre-design work phase: Pre-sign off, Discover, Define, Design, Detail and Deliver; each of which have their own assigned tasks and sub-tasks. As with Case study 1, this provides participants with context to consider influential factors from.

Identify Key Project Stages

In addition to Key Project Resources, the Key Project stages were discussed and identified prior to the workshop, as clear stages were already in effect at the consultancy. These stages are based on an adapted form of the Design Council's Double Diamond (Norman, 2013) and included a pre-design work phase: Pre-sign off, Discover, Define, Design, Detail and Deliver; each of which have their own assigned tasks and sub-tasks. As with Case study 1, this provides participants with context to consider influential factors from.

Table 3 – Factors for Person-hour influence in Design Projects at DCB

Grouped Factor Name	**Factors**
Client "Gut Feeling"	Client experience, Judge of character, Scope alignment, Client "hand holding", Willingness to compromise, Scope Creep, Client Expectations, Client's motivation for product, Laws of physics, Decision making chain, Client responsiveness, Client management & University research project
Development Budget	Budget, Knowing budget, Funding
"Stuff" Happens	Hardware issues, Distractions, Personality Traits, Holiday & Illness, Bad day, Team Efficiency, Current resource of team
Definition Level (Inputs)	How developed the brief is, Key milestones, Defined market
Regulatory Complexity	Regulatory Complexity
Geography	Supplier proximity, Travel time/proximity, Environmental parameters
Designer Experience	Designer Experience, (User research), (Sketch/Ideation), (CAD/Technical), Project Management, (Fusion/Solidworks), Motivation, (Presentation putting together), New people, Material Knowledge, Manufacturing Knowledge
Product Complexity	No. of standard/unique parts, Prototypeability, Testing, Novelty, IP, Complexity, Rendering, Functional requirements, Build time, Part Types
Delivery Output Complexity	Supplier risk factor, Chinese New Year, Supplier liaison, Product Budget, Volume of product, Material diversity, Process diversity
Communication complexity	Communication, No. of stakeholders, No. of subcontractors

Identify Every Potential Factor That Influences Design Project Resources

This task required participants to create an exhaustive list of every factor that may influence the number of person-hours a project would require for any, or all phases of a design project. During the informal discussion and brainstorming session between all the participants, and unprompted by the researcher, the participants approached the task by addressing each design project phase, identifying those factors that influenced each respectively. Doing so created seven distinct categories, one for each stage, plus one for factors which effected more than one, or all of the stages. Sixty-three (63) different factors were suggested, shown in the right had column of Table 3, and were then regrouped into ten (10) different categories, shown in the left hand column of Table 3. This clustering process helped identify similar terms which had been applied to separate stages of the design process and allowed for common themes to be established. The stage-by-stage process allowed the participants to define each of the clustered factors as by the varied ranges of terms for similar factors. However, this process also allowed for some terms to be suggested that were activities/tasks, rather than factors, these have been placed in parenthesis in Table 3. Future case studies will see this approach formalised within the tasks, with the researcher overseeing the process to prevent non-factor suggestion

Identify Key Factors From List

To avoid the inter-participant influence observed during the key factor selection process in Case Study 1, participants were asked to secretly select what they considered to be the most influential factors, ranking them from most influential to least. These votes were then counted to not only capture what was collectively perceived to be the most influential, but also the perceived ranks of each subsequent factor, shown in Table 4. As *Delivery Output Complexity* and *Designer Experience* received the same number of votes, the participants decided that *Delivery Output Complexity* was more influential, concluding that the top four most influential factors were *Client Gut Feeling, Definition Level Inputs, Product Complexity* and *Delivery Output Complexity.* This was a more effective voting system, eliminating the potential influences of the "sticky dot" selection method and also captures the ranked order of the factors per participant.

Table 4 – Factors for Person-hour influence in Design Projects at DCA

Factor	Ranked Vote					Points Score					
	1	***2***	***3***	***4***	***5***	***5***	***4***	***3***	***2***	***1***	
"Stuff" Happens	0	0	0	0	0	*0*	*0*	*0*	*0*	*0*	***0***
Client Gut Feeling	3	0	0	2	0	*15*	*0*	*0*	*4*	*0*	***19***
Development Budget	0	0	1	0	0	*0*	*0*	*3*	*0*	*0*	***3***
Definition Level Inputs	0	3	1	0	2	*0*	*12*	*3*	*0*	*2*	***17***
Regulatory Complexity	0	0	0	0	0	*0*	*0*	*0*	*0*	*0*	***0***
Geography	0	0	0	0	0	*0*	*0*	*0*	*0*	*0*	***0***
Designer Experience	0	2	1	1	1	*0*	*8*	*3*	*2*	*1*	***14***
Product Complexity	2	1	0	0	2	*10*	*4*	*0*	*0*	*2*	***16***
Delivery Output Complexity	1	0	1	3	0	*5*	*0*	*3*	*6*	*0*	***14***
Communication Complexity	0	0	2	0	1	*0*	*0*	*6*	*0*	*1*	***7***

Factor Analysis & Discussion

The following section of this paper will analyse and discuss the seven key influential factors on design project length, as identified and voted for by the participants by DCA and DCB during each respective case study. These factors are collated in Table 5.

Product Complexity

It may be considered a foregone conclusion that the complexity of the product to be designed (i.e. a spoon vs. a jet engine) will have an impact on the length of time that a project takes. This is reinforced by its inclusion on both shortlists of factors.

The defining factors of this term suggested in Case Study 2, provide a diverse list of elements, with some specific categories. *Number of unique parts / Standard components* (the ratio of unique parts to standard parts), *Prototypeability* (the ease by which a prototype of a design concept can be made), *Build time* and *Types of parts / mechanisms* all relate to the ease by which the product can be made, either for final production, or during development. Likewise, the factors of *Prototypeability* and *Testing* are factors specifically about the physical development of a product. They are phenomena experienced as a result of a product's physical attributes.

Table 5 – Collated Influential Factors

DCA Factors		**DCB Factors**	
Product Complexity	Prior Knowledge	Client Gut Feeling	Delivery Output Complexity
Project Scope	Materials Budget	Definition Level Inputs	(Designer Experience*)
Regulatory complexity		Product Complexity	**[Ranked 5th voted out]*

In each case study, the participants were asked to identify some hypothetical limits to a potential measurement scale for each factor. As a measure of complexity, the DCA participants proposed that a maximum and minimum level be based in the number of parts the product would likely have, a contrast to the abstract "simple/complex" from DCB.

Clarity of Brief

This factor, conceived by The term *Project Scope*, identified by the DCA Participants, and *Definition Level Inputs* were both terms defined by their respective participants relating to the project brief. Specifically, the clarity and specificity of the brief, reinforced by the DCA participants suggested that *Project Scope* be measured on a scale between "Ambiguous" and "Defined"; and the DCB participants suggesting a four-point checklist as a measure of clarity. This list includes "Scope definition", which in that context relates to whether the scope of the project has been established; "Budget", is there a clear established budget for the project; "Background Research", has the client provided their own research in conjunction with the brief; and "Milestones", has the client defined specific timeframes that the project should be completed within.

Delivery Output Complexity

This factor, conceived by the DCB participants, was initially described as a product of: *Supplier risk factor, Chinese New Year, Supplier liaison, Product Budget, Volume of product, Material diversity* and *Process diversity*. These terms relate to issues surrounding the manufacturing of products, yet range in scales of measurement and degrees of subjectivity are equally varied. Terms such as *Chinese New Year, Volume of product* and *Product Budget* are easily defined, as New Year will always fall between 21st January and 20th February each year, and an intended volume and budget will be set from the project outset, albeit potentially preliminary. Yet other factors relate to the design team's experience (see Section 5.4), such as *Supplier risk factor* and those relating to the physical manufacturing of the product (i.e. *Material diversity, Process diversity*, etc.) are therefore not easily assessed from the project start, as they are subject to change and are dependent on the outcome of the ideation activities of the design process. During a second discussion between participants, they wanted to clarify their definition of Delivery Output Complexity, using the information gathered exclusively from the brief and preliminary discussions with the client. The participants agreed on a list of tasks which would add to the duration of a project as elements of this factor. Such tasks as: Branding & Marketing, Packaging, Manufacturing planning, Quality Control, App Development, etc. These are project elements which would increase the project length and could be easily measured, or quantified, from the project outset through questioning.

Designer Knowledge and Experience

The terms *Prior Knowledge* and *Designer Experience* are clearly related, as one of the foundations of knowledge is experience. The DCA participants defined the measurement scale of *Prior Knowledge* as being between "no knowledge" and "expert"; DCB participants did not specifically define a scale for *Designer Experience*, however the terms used to define the factor (see Table 3), include multiple instances of the term "knowledge". The measurement of knowledge and experience is a particular challenge and is inherently subjective, yet experience is key to the modelling and planning of design processes (Eckert and Clarkson, 2010) and therefore must be considered a critical factor.

Regulatory Complexity

The term *Regulatory Complexity* occurs in both case studies, yet only the DCA participants regarded it as a key influential factor, assigning a scale range between "simple" and "complex". DCB participants gave no further terms to apply to this phrase, yet both teams discussed legislation and country and international standards as contributing elements to the term. Both teams further agreed that the bureaucratic tasks required to adhere to said standards would require significantly more time to accomplish.

Designer's Intuition of the Client

The *Gut feeling of client* is a generalised term for a tacit intuition that the management of DCB have on their client. It is informed by the contributing elements, *Client experience, Judge of character, Scope alignment, Client "hand holding", Willingness to compromise, Scope Creep, Client Expectations, Client's motivation for product, Laws of physics (*a client's ability to rationally understand what can, and cannot be done*), Decision making chain, Client responsiveness, Client management, Curveballs and interruption,* and *University research project*. Other than *University research project*¸ (a simple binary categorisation) none of these elements can be fully assessed objectively. When the researcher asked for further information on how the participants would measure these traits, the participants synthesised a four-entry checklist which clients could be objectively measured against (*Technical Experience*, *Business Experience*, *Personality* and *Competency*), based on their interactions with the design team and the information they provided. One can draw a partial link between these categorisations the discussions of *personality* (Bryson and Delbecq, 1979). Yet Bryson and Delbecq's discussion of personality relates to that of the design team, not that of the client, and do not refer to the designer's perceptions and intuition of the client. Remarks in other literature entries refer to *priorities* which may have similar links, yet do not expand beyond the factor name.

Materials Budget

Materials Budget understandably influence project length. One can argue that the larger the budget, the quick stages of the design process can be competed, by "throwing money at the problem". Yet with *Materials Budget* specifically, the participants of DCA focused on the prototyping and physical concept development work of a design project. The "right first time" approach to hardware development would be time consuming, whereas an iterative hardware development approach would require a larger budget, but, from their experience, would take less overall time.

Conclusions & Recommendations

The findings in literature on the influential factors of time in PPD projects is varied, with the most common factors ranging from the product complexity and project budget, to process controls & tools, and the priorities and motivations of the stakeholders. In industry, these factors are equally varied, with the most influential factors of: *Product Complexity, Clarity of Brief, Delivery Output Complexity, Designer Knowledge and Experience, Regulatory Complexity, Designer's Intuition of the Client* and *Materials Budget*. The research questions posited at the beginning of this paper will be addressed in turn.

Do the factors considered to be most influential of PDD project length in literature match those of practicing Product Designers and Product Design Engineers?

In the main, the factors from literature do match, or have similar categorisations to those found in industry, with those matching having only slight variations, or have similar elements distributed among different factors. Yet the perspectives from which some factors are viewed, differ between the definitions found in the literature and those held by the design teams, such as Bryson and Delbecq's approach to personality, those of the design team themselves; and the perspectives shared by the participating design team, who consider the client's personality, referred to as their *intuition of the client*.

Are there factors that are considered influential in industry, which aren't greatly covered in literature?

There seems to be two notable factors found in industry which to not correspond to those found in the literature, *Delivery Output Complexity* and *Designer's Intuition of the Client*.

There are elements of each of these factors to be found in literature, but the sentiment stated by the participants, do not match those literature-based elements.

Do the factors considered to be most influential of PDD project length vary between design agencies?

There all the shortlisted factors found during the case studies, only *Product Complexity* and *Clarity of Brief* are found in both. However, in there are more commonalities in between each of the consultancies' "longlists", such as geographical factors (proximity of stakeholders, manufacturing facilities, etc.). Yet with a sample size of two, these factors cannot be considered to be the most influential.

It is recommended that further investigations are conducted with a wider range of PDD consultancies, both within the UK and abroad, to gain a broader and more in-depth view of PDD project length influencing factors. Further investigation into the extent to which these factors influence PDD project time is also required to allow for the creation of an industry-based de facto list of factors, allowing for future projects to be more accurately evaluated and planned, allowing for improved efficiency of design efforts.

References

Andersen, E. S. (1996) 'Warning: activity planning is hazardous to your project's health!', International Journal of Project Management, 14(2), pp. 89–94.

Antonsson, E. K. and Otto, K. N. (1995) 'Imprecision in Engineering Design', Journal of Mechanical Design. ASME, 117(B), pp. 25–32. Available at: http://dx.doi.org/10.1115/1.2836465.

Bashir, H. A. and Thomson, V. (1999) 'Metrics for design projects: a review', Design Studies, 20(3), pp. 263–277. doi: https://doi.org/10.1016/S0142-694X(98)00024-6.

Brooks, F. (1975) The Mythical Man Month. Reading: Addison-Wesley.

Bryson, J. M. and Bromiley, P. (1993) 'Critical factors affecting the planning and implementation of major projects', Strategic Management Journal. John Wiley & Sons, Ltd., 14(5), pp. 319–337.

Bryson, J. M. and Delbecq, A. L. (1979) 'A Contingent Approach to Strategy and Tactics in Project Planning', Journal of the American Planning Association. Routledge, 45(2), pp. 167–179.

Christensen, K. S. (1985) 'Coping with Uncertainty in Planning', Journal of the American Planning Association. Routledge, 51(1), pp. 63–73. doi: 10.1080/01944368508976801.

Earl, C., Johnson, J. and Eckert, C. (2005) 'Complexity', in Clarkson, J. and Eckert, C. (eds) Design process improvement: A review of current practice. London: Springer London, pp. 174–197.

Eckert, C. M. and Clarkson, P. J. (2010) 'Planning development processes for complex products', Research in Engineering Design, 21(3), pp. 153–171. doi: 10.1007/s00163-009-0079-0.

Norman, D. A. (2013) The design of everyday things. Revised an. Basic Books; New York.

Rezania, D., Baker, R. and Burga, R. (2016) 'Project control: an exploratory study of levers of control in the context of managing projects', Journal of Accounting & Organizational Change. Emerald, 12(4), pp. 614–635. doi: 10.1108/JAOC-10-2015-0084.

Rondinelli, D. A., Middleton, J. and Verspoor, A. M. (1989) 'Contingency Planning for Innovative Projects', Journal of the American Planning Association. Routledge, 55(1), pp. 45–56.

Vaagen, H., Kaut, M. and Wallace, S. W. (2017) 'The impact of design uncertainty in engineer-to-order project planning', European Journal of Operational Research, 261(3), pp. 1098–1109.

Xu, D. and Yan, H.-S. (2006) 'An intelligent estimation method for product design time', The International Journal of Advanced Manufacturing Technology, 30(7), pp. 601–613.