Towards a Framework of Choices Made During the Lifecycles of Process Models

Conference or Workshop Item

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

TOWARDS A FRAMEWORK OF CHOICES MADE DURING THE LIFECYCLES OF PROCESS MODELS

K. Gericke, C. M. Eckert and D. Wynn

Keywords: process modelling, model building, design process, product development

1. Introduction

The product development process of complex engineering products typically involves the collaboration of hundreds of experts often located across the world over a period of several months or years. Delivering these products depends on effective and efficient product development processes. Good models can support the management of processes and provide an understanding of the connectivity between different activities. Different stakeholders in an organisation use a large number of different models at the same time [Eckert and Clarkson 2010] with a variety of units of planning and a different scope according to their personal purpose. Academic research has developed tools and methods for process modelling for industry using a variety of different process modelling platforms each of which supports slightly different content. In some cases, they follow a very different logic of model building. The tools provide visualizations of the process as well as the ability to analyse product development processes, in principle enabling improvements of the modelled process and of its execution. However, analyses of a process depend fundamentally on the properties of the underlying process model. For example, a cluster analysis of task depends on the initial dependencies being captured in the model. The quality of the model is usually not emphasised in the academic literature and most analysis software assumes that models are accurate and appropriate. This paper reflects over the choices the processes modellers need to make in the course of building processes and proposes a framework to show how the choices are related to each other.

2. Literature review

2.1 Characteristics of design processes affecting process modelling

Design processes in practice are complex, iterative and affected by the product under development and their context [Eckert and Clarkson 2005], [Kreimeyer 2009], [Maier and Störrle 2011], [Gericke et al. 2013]. They differ from e.g. manufacturing processes and typical business processes in companies in that they are more dynamic and have greater variability [O'Donovan et al. 2005], [Vajna 2005]. These characteristics pose a challenge for modelling design processes. Process modellers usually cope with the issues of dynamism and variability by simplifying real processes, which requires from models and users both flexibility and the ability to interpret models properly.

2.2 Types of models and the level of detail of models

Design process models can be classified in different ways. For instance a distinction may be made between phase-based and activity-based models [Blessing 1996], [Lawson 1997]. An alternative is to

distinguish between problem-oriented and solution-oriented models [Blessing 1996], [Wynn and Clarkson 2005] and/or between prescriptive and descriptive models. These classifications describe essentially-orthogonal dimensions, i.e. they do not exclude each other.
Many models are generic applying to process at all scales and in many domains. However, complex engineering processes are interdisciplinary endeavours involving different business functions and departments. Thus, a design process interacts with other processes within a company [Maier and Störrle 2011]. The interactions between different business functions, i.e., departments in a company, result in different views on the design process. While a design team needs to oversee and understand the detailed activities and their dependencies that form the process, other departments need to understand how a design process is interdependent with accompanying processes and may be less interested in the detailed activities.
Even groups involved in similar tasks will have specific interests and needs for information, thus will have specific views on the process [Browning 2009], [Gericke and Blessing 2012]. Different models of the same process thus often coexist, representing different perspectives on a process, containing different information at differing levels of detail [Qureshi et al. 2013] (see Figure 1).

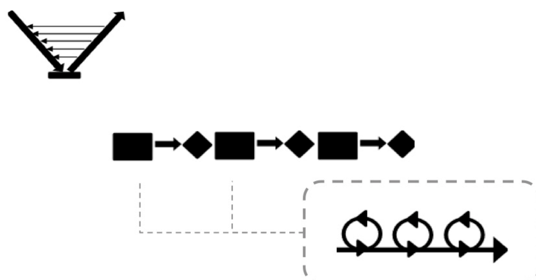

Figure 1. Co-existing views on the design process (after [Qureshi et al. 2013])

Coexisting views imply that different purposes for creating and using process models do exist. Browning et al. [Browning et al. 2006] distinguish the following purposes:

- Project visualisation (Actions, interactions and commitments; Customised views)
- Project planning (Making commitments; Choosing activities; Structuring the process)
- Project execution and control (Monitoring commitments; Assessing progress; Re-directing; Re-planning)
- Project development (Continuous improvement; Organization learning and knowledge management; Training; Compliance)

While models can be distinguished by their purpose, rationale for modelling and scope, they can also differ in terms of detailing. Depending on the purpose the content of models and their level of detail will differ [Browning 2010].
Modelling of design processes can be supported by a variety of modelling formalisms and notations, e.g., Integrated Definition Method (IDEF0, IDEF3) [Knowledge Based Systems Inc. 2010], Gantt Diagram [Gantt 1919], network planning techniques [Kerzner 2013], Design Structure Matrix (DSM) [Eppinger and Browning 2012], and Signposting [Clarkson and Hamilton 2000].
Some modelling approaches comprise only a small number of elements while others enable (or require) modellers to include additional information into a process model, thus increasing the level of detail of process models. The entities covered in a particular model vary significantly between different modelling formalisms [Browning et al. 2006], [Kreimeyer 2009]. Information (entities) that may be considered in a product development process model include, e.g. [Browning 2009], [Kreimeyer 2009]: Responsibilities (persons, roles, departments), Duration of activities, Required resources, Dependencies (e.g. between activities), Deadlines, Progress of work, Work results (attributes, documents, etc.), Confidence into estimates and forecast regarding duration, cost etc.

2.3 The relationship between a model and reality

As noted above a variety of modelling formalisms, notations and classifications of process models (e.g., descriptive vs. prescriptive) exist. While the prescriptive-descriptive distinction seems to apply to design

process models which either describe existing processes or prescribe an (ideal) process, this is blurred in reality as prescription requires knowledge of good practice. Furthermore, models that are used to guide actions generate the reality, which complicates such a distinction and makes it difficult to apply.
Process models are like other models simplified (i.e. schematic) representations of reality. While highlighting certain information other information is neglected. The selection of represented information and the way it is modelled depends on the purpose of the model [Browning et al. 2006], [Browning 2010], [Eckert and Stacey 2010].
Models are also often "wrong", i.e. recognised to contain inaccuracies and oversimplifications. As long as simplifications and limitations are understood, this is not necessarily a problem because simplification is needed to model reality and focus attention on a specific problem, which is resolved with the help of the model. Unfortunately, assumptions and limitations are often not documented which can become a problem if a model is used for a different purpose that originally intended, or by a different person.

2.4 Guidance for model development

Many process modelling approaches, formalisms and notations exist. They have individual strengths and limitations and have different degrees of suitability to support process modelling for any specific purpose [O'Donovan et al. 2005], [Amigo et al. 2013]. Some might be not ideally-suited for creating process models that serve a specific need. Thus it is important to consider such limitations when creating a model as well as to communicate purposes, assumptions and limitations that guided and were known during model building, to guard against models being used for an inappropriate purpose.
Little support for creating design process models exists. Such support focuses usually on the application of specific formalisms and notations (e.g., Gantt [Gantt.com 2012], BPMN [OMG 2011]) often in contexts different from product development such as business process modelling or general project management. The underlying choices for selecting a specific modelling approach, formalism or notation, the selection of relevant information, the evaluation of model quality, the implementation of a process model in a company, its communication, its use, maintenance and end of life are neglected so far. Few publications describe good practice in design process model building and provide context-specific recommendations (for one example see [Kerley et al. 2009]).

3. Methodology and overview of the contribution of the paper

Any action based on process models and analysis of process models depends to same extend on the quality of the models. This is partly a question of the availability of information, but also how the modeller chooses to represent the data. The research discussed in this paper builds on two sources: authors experience in process modelling over the last 20 years and discussions during a series of workshops of the Modelling and Managing Engineering Processes Special Interest Group (MMEP SIG) of the Design Society, which addresses product development processes and process modelling and their analysis, improvement and use in varying contexts [Gericke and Eckert 2015].
The model presented in this paper is a synthesis of the work on process modelling by the authors and their research groups over many years. The paper presents a framework of modelling choices that affecting process modelling. Note that by modelling choices we refer to the decisions about the way to describe models in terms of the modelling language, the model granularity etc., rather than describing choices that are part of the modelled design processes themselves with the aim of the understanding the consequence of these choices, as the literature on choice modelling would.
To raise awareness amongst the group members for the choices the modeller makes in modelling we asked all twelve participants of a workshop in November 2014 to create a model of the process of doing a PhD without prescribing the method or scope of the models. Based on the prepared models the participants of the workshop were guided using a set of open ended questions to reflect on the choices they made during modelling the process before engaging in a facilitated discussion which was documented taking notes. Where necessary participants were contacted via e-mail for completion of notes and for clarification. Questions addressed in this reflection addressed e.g. the purpose of the model, intended users, expected benefit, inherent simplifications, used tools, the participants' satisfaction with the result and ides for improvement.

The questions are based on an initial model of the choices required before and during modelling design processes that the authors prepared prior to the workshop. The participant's reflections and the group discussion were used to develop the model further.
The improved model was then presented to a partially overlapping audience in a second workshop in May 2015 that was attended by 14 participants. Five participants, which did not attend the first workshop, were senior experts from academia and industry. During the second workshop, which was facilitated using metaplan technique, the participants were asked to discuss the spectrum of choices, influences on choices, effects of choices and possibilities for the evaluation of results. The outcome of the second workshop led to a revision of the model, which is presented in this paper.
The PhD process was selected as all participants have experience with it and therefore do not depend on a verbal description of the process, which would have biased the exercise. This paper uses the PhD process models to motivate and illustrate the issues. As process models are often reused for different purpose, section 5 discussed the different life cycle phases of a model that could affect. Section 6 draws attention to two aspects of modelling choices: the selection of the approach and representation chosen for modelling and the choices a modeller has within a given representation.

4. Different models for a similar process

Twelve participants coming from the UK, Germany, Luxembourg and France participated in the workshop. During the workshop the individually-prepared models were briefly introduced by the participants and then displayed on the wall (for examples see Figure 2). The differences between models, underlying assumptions, individual experiences as well as differences between the academic systems in which the processes are embedded were also discussed at the workshop.

4.1 Modelling the PhD process

During the workshop the participants explained the models briefly to each other.

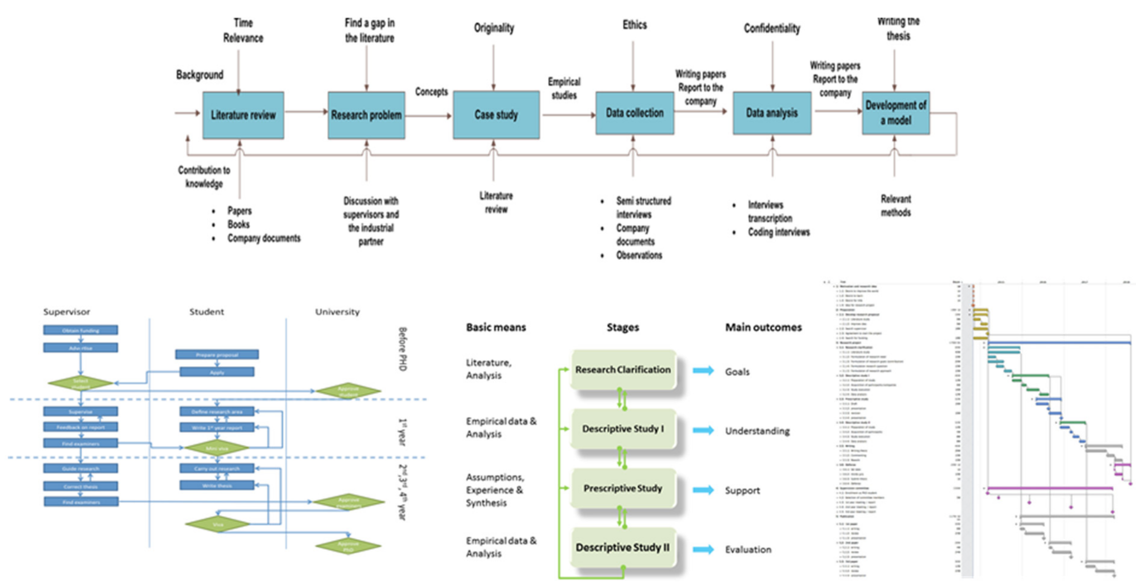

Figure 2. The PhD process as an example of different models of the same process

While the models and their print-outs varied in size, about half of the participants aimed to show their model on one sheet of paper. This is also not atypical for design process models in industry when practitioners are asked to draw informal models to illustrate their processes.

4.2 Visible differences

As the examples shown in Figure 2 illustrate, the models were different in a number of ways:

- The types of the models. Several participants had drawn flowchart models, which indicated the sequence of dependencies of tasks and used spatial arrangements to indicate concurrency of activities. Some people had drawn plans with indications when a particular task ought to be finished. While some models highlighted the linearity of some steps involved in doing a PhD others showed the iterative nature of many activities.
- Software package: Some models were drawn in specific process modelling software packages, while others were created in standard office software.
- The level of detail: While several models had a similar structure, they varied in the level of detail included in the model, from simple 4-task models to one model that covered several pages.
- The scope of the model: many models concentrated on the student's experience of doing a PhD, others also included the activities of other stakeholders, like the supervisors or the university administration.

4.3 Hidden differences

There were also several differences between the models, which are not immediately apparent. All the models were presented and on the surface looked finished. However, this reflected the participants experience with the modelling software, rather than their understanding of the PhD process. Everybody had a different level of experience from nearly 20 years as PhD supervisor to just having started a PhD. The experience and understanding that the modellers had of the process was not visible. The experience was also reflected in the view point that the modeller took on the process. This influences the tasks that the modellers were aware of or chose to include in the model and dependencies between them. Some of the models also had timelines in them. Just by looking at a timeline it was not clear whether the modeller intended to convey an expected timing, a prescribed timing or something reflecting actual timing in practice.

5. The life-cycle of models

As Eckert and Clarkson [Eckert and Clarkson 2010] point out, sometimes the same model is used at the beginning as a means to understand and prescribe a process, later to monitor or direct a process, and at the end as a record of the design process that has occurred. This indicates that process models have a lifecycle of their own. Not all models have the same lifecycles, since design process models exist at very different scales and permanencies from a very personal model that an engineer creates to plan their day to models that cover the entire product development process and are used through the organisation for the duration of the entire product. A process model can be thought of as an artefact in its own right that is created, used and eventually falls into disuse.

5.1 Life cycle phases of process models

Figure 3 shows the lifecycle stages of process models. Process modelling starts with the need for a model. The needs can range from formal requirements to a personal desire to gain a better understanding of an existing or future process. In understanding the needs for a model, the purpose of the models and the intended use of the model should become clear.

Only under particular circumstances will it be possible to recognise a need for a model and proceed straight away to building a model. Normally the process needs to be analysed and information about the process needs to be gathered. For example, managers need to talk to their team members to understand what tasks they are expecting to need to be carried out to develop or adapt a component. At this stage, decisions need to be made regarding how the models will be created.

During the modelling stage the actual model is constructed and fundamental decisions are made about the content of the model, both in terms of scope and the detail of information that is included. The development of understanding and modelling go hand-in-hand; this can be a highly iterative process involving finding out about the process, thinking about the process, and representing it in a model.

Once the model is finished it often needs to be communicated to other stakeholders who need to approve or use the model. Model users might require both an explanation of the content and also an explanation how the representation should be read and interpreted, if they are not familiar with it. Communicating a model across an entire organisation can require considerable effort.

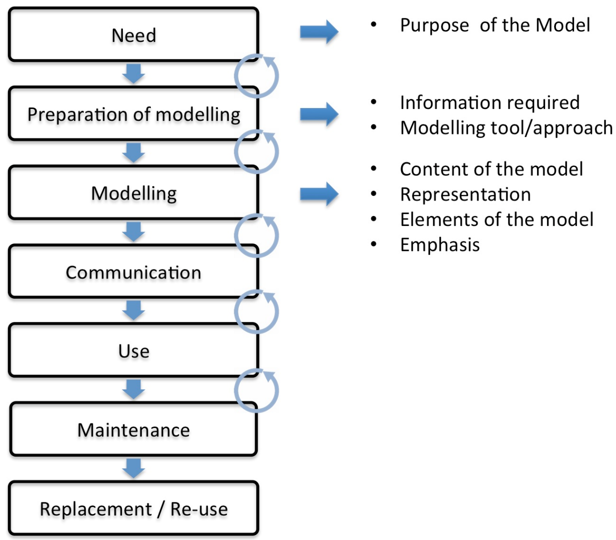

Figure 3. Lifecycle of process models

Most models have a use phase, where the model is used by people within the organisations. This can include the users that were intended from the outset or others who have picked up on the model. Models capture the understanding of the process at the time the model is built, however the processes can change, so that the model needs to be updated and maintained to remain relevant. At the end of its intended life, the model will be discarded or be re-used for another purpose or another process.

5.2 Variations in the process lifecycle

This full process lifecycle with all the stages applies to formal models like gateway processes or stage-gate processes, where people put a huge amount of effort into developing and deploying models. The main function of other models lies in the understanding that is generated in building them, as this requires thinking through the process in a rigorous way, understanding the elements and their dependencies. In this case the model lifecycle only covers the first three stages of Figure 3. If gaining understanding is the main objective, then models are not necessarily completed. As the perceived value of processes modelling often lies in building the models, the models are later not adapted to update them as the process changes; or another model may be generated without an obvious link to previous models.

6. Choices about modelling and influences on those choices

All the stages of the process model lifecycle have a profound influence on the choices that modellers need to make in building their process models. They need to consider each of the stages in deciding how and when they build a model. There is a particular order in which decisions about modelling should ideally be made, however earlier decisions constrain later ones.

6.1 Prior to modelling

Many of the choices and decisions that affect process modelling and the resulting process need to be made before the actual modelling process begins, although they might be revisited later. A number of questions should be considered that affect choices having an influence on the actual model building and later phases of the model lifecycle: Why is the process model built? (What is the purpose of the model?) What will be represented in the process model? (Influenced by understanding of the process) Who should/will model the process? (Influenced by the skill of the modeller) For whom is the process model built? (What is the skill level of likely users?) How is the process model built? (What modelling approach should be used?). These choices and issues are elaborated in the next subsections.

The purpose of the model

Because models are abstractions created for a particular purpose, the purpose(s) of the models need to be considered early on (although this may evolve later). For example, the following questions need to be considered before starting the modelling process:

- Will the model describe an existing process?
- Will the model support process planning?
- Is the main purpose of the model to help thinking through the process?

Modelling is sometimes started with great enthusiasm by people who underestimate the effort involved in modelling complex processes. If the aim is too ambitious, the effort of modelling may outweigh the benefits or the model itself might have little value if it is never completed or not trusted to be accurate.

Understanding of the process

People understand processes to a varying degree and much of the understanding that outsiders or even participants of a process have is patchy and uneven. For large-scale processes there is a limit of how much of a process can be understood by a single person or even a team with reasonable effort. Therefore, a decision needs to be taken about the scope of the process model or the level of detail that is required and can be achieved. Unless a process is repeated frequently in a similar way, and significant changes of the process are unlikely, this step of gaining an understanding can be time-consuming.

Skill of the modeller

Process modelling is an activity that people need to learn. They need to become familiar with a formalism, a notation or a tool in which the model will be built. They need to learn to avoid significant gaps or inconsistences in the model and learn how to express particular aspects of a process. For example, when the modeller is confronted with a cluster of interconnected tasks, it is necessary to identify meaningful chunks and key dependencies to provide a clear(er) picture of the process.

Skill of the user

Similar factors apply to the user of process models. They need to be able to understand the model once it is generated. Thus the skills and experiences of users need to be considered in the process of building the model. It is important choose an appropriate modelling approach, because the skills of the users constrain the model content and the model building process. In that case, it becomes a strategic decision whether the benefit of using a new modelling approach is worth the additional effort for implementing training enabling the use of a new modelling approach.

The modelling approach

Processes can be modelled using many different approaches (formalisms and notations) using a variety of different tools, which all can be useful in some circumstances. Therefore, the modeller needs to think about which modelling approach offers the right characteristics to meet the intended purpose. A flowchart shows a sequence of activities and their feedback loops clearly. A DSM shows the dependency between tasks clearly, but does not necessarily imply a temporal order. A Gantt chart shows the timing of tasks, but does not necessarily show their dependencies. The selection of a suitable modelling approach, modelling formalism or notation should be guided based on the decision about the purpose(s) of the process model.

Before process modelling can begin it is important to decide on the scope of the model and aspects of the process that are modelled. Product development processes are interconnected with other processes for example through shared components or supplier processes, sub-processes are connected to other sub-processes, yet it is rarely possible to capture all of these processes in one model. Where the focus is set and the boundaries are put are choices that need to be made from the outset, even if the details of the boundary might change as the understanding of the process increases. This also needs to be communicated to the user of models to make a distinction between elements that do not exist in the process and those that are not included in the model.

6.2 Choices during modelling

Once the choices prior to modelling are made, many more choices arise and need to be made during the modelling process. The selected modelling approach defines to a certain extent the structure which the model can have. For example, some modelling approaches allow hierarchical modelling, highlight iteration loops etc., while others do not. The modelling approach also determines the kind of elements that a model can contain, for example determining whether it can contain tasks, resources, deliverables, parameters, decision points and so forth.

While basic process modelling concepts like tasks and information flows seem clear on the surface, it can be difficult in practice to decide how the concepts should be applied to best effect. For example, a task seems a simple enough concept referring to a clearly defined piece of work. However, in practice tasks may blend into each other, for example the synthesis step of defining a component's geometry and an analysis of its behaviour can be difficult to separate. As Figure 4 illustrates this particular example could reasonably be modelled in different ways:

- As a single task, because it is difficult to distinguish between the two;
- As two consecutive tasks, because logically analysis follows synthesis;
- As overlapping tasks, because analysis often begins before the synthesis step has ended;
- As parallel iterative tasks, because analysis and synthesis are often done together.

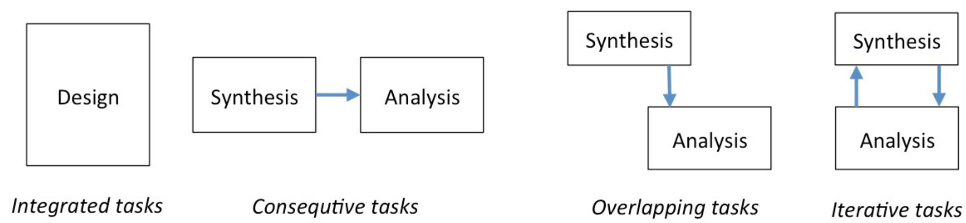

Figure 4. Some options for modelling two strongly-connected tasks

Elements of a process are also often shared, for example resources or tasks can be shared across different elements of a process, some of which might be outside the scope of the model. Other elements might seem too trivial to include or not directly contribute to a process as such, but take up time and resources. For example, few process models include meeting or staff development activities, even though these can take up significant time. It is often not clear how or whether such activities should be indicated in a model and how they should link to other activities, and the default choice is often to leave them out.

In all modelling approaches there is a choice about the level of detail the modeller wants to include. Some modelling approaches allow explicit hierarchical modelling which allows for flexibility on this issue, however in all approaches the modellers need to decide at what level of detail they want to represent the process. This also affects the choices regarding the modelling of connected tasks as shown in Figure 4. A very abstract model might only represent a single task, which is broken down in two tasks at the next level of detail. A more detailed description might reveal the dependencies and iterative nature of tasks, which on closer inspection might be decomposed into a sequence of different overlapping tasks.

6.3 A framework of modelling choices

The choices relevant to processes modelling affect each other, as depicted in Figure 5. Thus they should ideally be considered in unison.

As shown in Figure 5, the fundamental decision that influences the entire process lifecycle is the definition of the purpose of the model, which impacts the initial selection of a modelling approach and later the selection of the elements that will be represented in the model. The modelling approach determines what kind of information is represented in the models, while conversely knowing what information will need to be expressed should influence the selection of the modelling approach. What can be and should be in a model also depends on the knowledge and skill of the people who are building and using the model.

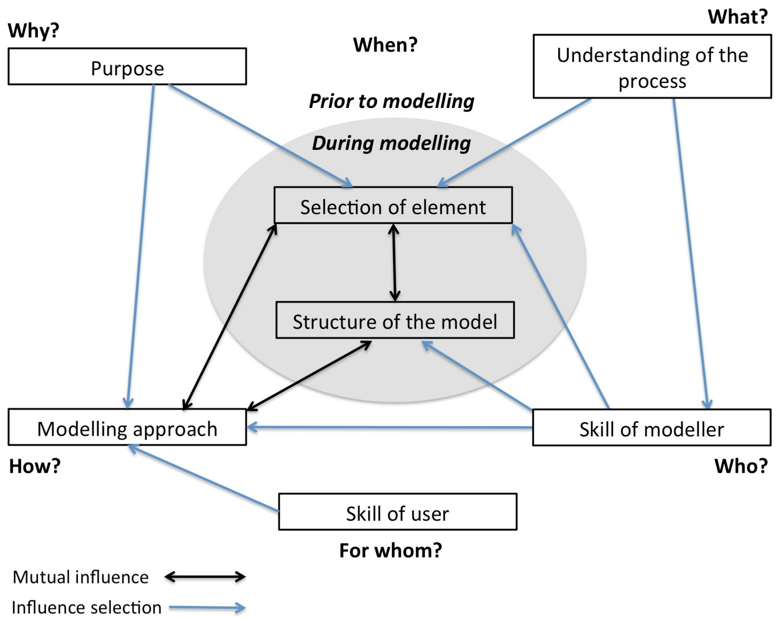

Figure 5. Framework of modelling choices

7. Conclusion

This paper has discussed some of the choices that modellers need to make during design process modelling. These have a profound effect on what the models can be used for and therefore can potentially affect the process that they are modelling. The decisions are rarely made explicit or discussed when building models or interacting with models. In the design research community there is relatively little literature on how to build process models.

The example of the PhD processes was a small scale exercise and the participants invested varying efforts into building the models. However, we have observed similar issues with process models in industry. These also often present a mixture of as-is, as-should-be and/or as-should-have-been description. From the models itself it is often not apparent how well the people who have built the model have understood the process that they are modelling. Often the creator of the model is not recorded on the model itself, so that not everybody in the organisation will know. The purpose that a model has originally been generated for is typically not recorded with the models, so that if one sees the models without an explanation, it is not clear what the intended use of the model is. Many of these issues apply also to industrial processes. In further work we will analyse the choices we have made in our own modelling in the past as well as the description of the modelling choices provided in the literature to validate the framework.

Acknowledgement

We would like to thank the participants of the MMEP workshops for discussing earlier versions of this work.

References

Amigo, C. R., Iritani, D. R., Rozenfeld, H., Ometto, A., "Product Development Process Modeling: State of the Art and Classification", In: Abramovici, M., Stark, R. (Eds.), Smart Product Engineering, Proceedings of the 23rd CIRP Design Conference. Bochum, Germany, Springer, Heidelberg, 2013, pp. 169-179.

Blessing, L., "Comparison of design models proposed in prescriptive literature", In: Social Shaping of Design: The Role of Design in the Shaping of Technology, The European Committee, 1996, pp. 187-212.

Browning, T. R., "On the alignment of the purposes and views of process models in project management", Journal of Operations Management, Vol.28, No.4, 2010, pp. 316-332.

Browning, T. R., "The many views of a process: Toward a process architecture framework for product development processes", Systems Engineering, Vol.12, No.1, 2009, pp. 69-90.

Browning, T. R., Fricke, E., Negele, H., "Key concepts in modeling product development processes", Systems Engineering, Vol.9, No.2, 2006, pp. 104-128.

Clarkson, P. J., Hamilton, J. R., "'Signposting', A Parameter-driven Task-based Model of the Design Process", Research in Engineering Design, Vol.12, No.1, 2000, pp. 18-38.

Eckert, C. M., Clarkson, P. J., "Planning development processes for complex products", Research in Engineering Design, Vol.21, No.3, 2010, pp. 153-171.

Eckert, C. M., Clarkson, P. J., "The reality of design", In: Clarkson, P. J., Eckert, C. M. (Eds.), Design Process Improvement A review of current practice, London, 2005, pp. 1-29.

Eckert, C. M., Stacey, M. K., "What is a Process Model? Reflections on the Epistemology of Design Process Models", In: Heisig, P., Clarkson, P. J., Vajna, S. (Eds.), Modelling and Management of Engineering Processes, London, Springer, 2010, pp. 3-14.

Eppinger, S. D., Browning, T. R., "Design Structure Matrix Methods and Applications Engineering Systems", Cambridge MA, MIT University Press, 2012.

Gantt, H. L., "Organizing for work", New York, Harcourt, Brace and Howe, 1919.

Gantt.com, "Creating Gantt Charts", Available at: <http://www.gantt.com/creating-gantt-charts.htm>, 2012.

Gericke, K., Blessing, L., "An analysis of design process models across disciplines", In: Proceedings of the 12th International Design Conference DESIGN 2012, Cavtat, The Design Society, Glasgow, 2012, pp. 171-180.

Gericke, K., Eckert, C., "The long road to improvement in modelling and managing engineering design processes", In: Proceedings of 20th International Conference on Engineering Design, Milan, Italy, The Design Society, Glasgow, 2015.

Gericke, K., Meißner, M., Paetzold, K., "Understanding the Context of Product Development", In: Proceedings of 19th International Conference on Engineering Design, ICED'13, Seoul, Korea, The Design Society, Glasgow, 2013.

Kerley, W. P., Wynn, D. C., Moss, M. A., Coventry, G., Clarkson, P. J., "Towards Empirical-derived Guidelines for Process Modelling Interventions in Engineering Design", In: Proceedings of 17th Conference on Engineering Design, Stanford, CA, The Design Society, Glasgow, 2009.

Kerzner, H., "Project Management - A Systems Approach to Planning, Scheduling and Controlling", 11th ed., Hoboken and New Jersey, John Wiley & Sons, Inc., 2013.

Knowledge Based Systems Inc., "IDEF Family of Methods - A Structured Approach to Enterprise Modeling & Analysis", IDEF Family of Methods, Available at: <http://www.idef.com/>, 2010.

Kreimeyer, M. F., "A Structural Measurement System for Engineering Design Processes", Doctoral dissertation, Universität München, 2009.

Lawson, B., "How designers think: The design process demystified", 3. ed., Amsterdam, Elsevier/Architectural Press, 1997.

Maier, A., Störrle, H., "What are characteristics of engineering design processes?", In: International Conference on Engineering Design ICED'11, Design Society, 2011, pp. 188-198.

O'Donovan, B., Eckert, C., Clarkson, J., Browning, T. R., "Design planning and modelling", In: Eckert, C., Clarkson, J. (Eds.), Design Process Improvement: A review of current practice, London, Springer, 2005, pp. 60-87.

OMG, "Business Process Model and Notation Version 2.0", Available at: <http://www.bpmn.org/>, 2011.

Qureshi, A. J., Gericke, K., Blessing, L., "Design process commonalities in trans-disciplinary design", In: Proceedings of 19th International Conference on Engineering Design, ICED'13, Design Society, 2013.

Vajna, S., "Workflow for design", In: Eckert, C., Clarkson, J. (Eds.), Design Process Improvement: A review of current practice, London, Springer, 2005, pp. 366-385.

Wynn, D., Clarkson, P. J., "Models of designing", In: Eckert, C., Clarkson, J. (Eds.), Design Process Improvement: A review of current practice, London, Springer, 2005, pp. 34-59.

Kilian Gericke, Dr.-Ing.
University of Luxembourg, Faculty of Science, Technology and Communication
162 A, avenue de la Faïencerie, L-1511 Luxembourg, Luxembourg
Email: kilian.gericke@uni.lu