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The Use of Design Assets as Potential Platform Elements in Two Manufacturing Disciplines

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Abstract. A vast body of research has described product platforms as strategic enablers for increased business competitiveness, but there is a lack of empirical research describing what types of assets that are used in industry as elements in a platform. Previous research has suggested a platform as a "collection of assets shared by a group of products" and also classified these assets into four transdisciplinary categories: Components, Processes, Knowledge and People and Relationships. This categorization is, however, too imprecise to identify the core assets needed to build a platform, and better guidance is needed. This paper presents a cross-case study of assets used in the product development process at two case companies. These represent two different product disciplines: Industrialized housebuilding, a sector within the construction trade, and Outdoor Power Equipment producing forest and gardening tools. The main contribution of the paper is a comparison of what formal and informal design assets that are used in the two disciplines.

Keywords. Product development, design assets, case study, product platforms

Introduction

Research suggests product platforms and modularization as ways for industry to leverage their assets to improve the efficiency, flexibility, and competitiveness. One foundation of platforms is based on economies of scale and scope: companies can achieve lower costs per unit by dividing indirect and fixed costs over a larger number of components, products, and product families [1]. This may be achieved by modularity [2], e.g. basing product families on smaller, standardized modules that can be combined in various ways to create a range of products. Furthermore, by developing a product platform, a company's ability to adapt and respond to changes in the market environment can be enhanced using a flexible product architecture that is adaptable to meet changing customer needs and market conditions. By developing a product platform, a firm can increase its product scope and its market adaptability, together with increased manufacturing volumes for components and modules that can lead to lower costs and increased efficiency in production and development [2]. Developing a product platform is challenging, since it requires a substantial upfront investment in terms of preparing the base for the product variants [3], which may involve designing a core architecture, identifying commonality and modularity, and optimizing the product variants. It also includes continuous maintenance to ensure that the platform remains effective over time.

Another challenge for introducing platforms is that the platform elements are defined in partly contradictory ways, such as a collection of components and modules [4], a group of related products [5], a technology applied to several products [6], or as consisting of assets shared by a set of products [7].

Design assets are the core of the Design Platform framework [3]. Its platform elements include various objects such as modules and physical components, the geometry of physical components (CAD-geometry) and production equipment. It also includes intangible elements such as design rules, processes, design information, and other resources. This resource-based view acknowledges that a company's assets and capabilities are the primary drivers of its competitive advantage, which also is difficult for competitors to replicate. Moreover, platform development is seen as an evolutionary process where assets are developed continuously, rather than a one-off investment that consume a vast amount of resources during the platform preparation that may be an overwhelming effort for many companies.

Given the importance of assets, previous research has suggested the introduction of formalized design assets for product development [3], [8], [9], purposely prepared for reuse between projects to provide support for a wide range of engineering activities. In the Design Platform framework [3], the preparation phase of platform development aims at creating a variety of transdisciplinary assets tailored for a specific company, covering relevant aspects of development, that can be efficiently reused to create new product families and its corresponding manufacturing system.

This paper presents a cross-case study of design assets used in product development at two companies, representing different product disciplines: Industrialized Housebuilding, a sector within the construction trade, and Outdoor Power Equipment producing forest and gardening tools. The presented research is a continuation of a study at the Outdoor Power Equipment company [8]. Here, several formal and informal design assets used by different types of engineers were identified. The present study is investigating if the same types of assets are used in another engineering discipline, by studying how engineers in similar roles perform a range of engineering activities.

The objective is to compare the use of formal and informal assets in the two disciplines. The purpose is to improve the management of design assets by integrating them as platform elements in a way that may be generally valid in product developing industry.

1. Related literature discussing design assets in platform development

Several authors discuss platform assets. Robertson and Ulrich [7] defines assets as the basis of a product platform and divide them into Components, Processes, Knowledge, People and relationships as constituents of a platform. Levandowski [10] introduces "development platforms" including concrete and abstract resources that are essential for supporting the platform development across all stages of a lifecycle. These rather vague definitions are complemented by source [8], describing which formal and informal design assets are used in practice at a department for mechanical design.

In source [9], the authors discuss and identify different types of platform assets that companies can develop to improve their product development processes: physical parts, CAD-models, component libraries, product structures, process models and activities, design guidelines and output from previous projects (such as parts, modules, products). These could be structured and incorporated in the platform of a company. This study

further highlighted the term "asset" and its implication for proper use, development, and maintenance also for resources that are not physical parts.

In product development, information, knowledge and learning are critical assets since these are the base used to synthesize new products [11]. The speed of the product realization process and the quality of the result may also be increased if knowledge assets are well prepared and has a high quality suitable for reuse. Therefore, substantial resources have been invested in knowledge development, and [8] propose to treat these intangible objects as assets in a platform. These can be reused in the organization to facilitate creation, codification, and transfer of knowledge. To overcome the challenges related to knowledge assets, a customized A3 format has been proposed to foster concise, easy to read guidelines [11]. Here, a structure and content more adapted to the tasks at hand is presented, to avoid time consuming searches for information in guidelines, project folders and documents.

Within Industrialized housebuilding, there are examples of platform assets. Popovic, et al. [12] present a study where design modules were developed, enabling configuration of residential houses using component parametrization and utilizing design assets in the design process. Stehn et al. [13] stress the need to both continuously develop and renew resources and competences, as well as to manage and maintain existing assets over time. Moreover, Product Lifecycle Management (PLM) has been suggested by Lennartsson, et al. [14] as a way to structure and support the implementation of design assets. The approach also improved the control over the product architecture.

To conclude this section, reflecting on the generic asset definition by Robertson and Ulrich [7] and the design assets classification of Raudberget, et al. [9], it is clear that better knowledge of what assets designers use in practice in different engineering disciplines is needed in order to identify potential platform elements.

2. Research approach and data collection

The presented research is part of a larger research project including 5 companies representing different domains and disciplines: industrial house building, automotive accessories, professional lighting, and garden products.

This paper presents a descriptive study building on datasets collected at a department for mechanical design of consumer products and a department for design of residential houses at an industrial house building company. The unit of study is a development unit through a 3,5-year joint-venture between the companies and the School of Engineering in Jönköping. The companies were selected since they both have a suitable product portfolio and have a clearly stated interest in better development methods. They have different sizes and represent different types of businesses. One common characteristic is that their products have a high variety and are highly influenced by architecture/ industrial design.

In a previous study [8], the data sets 1a and 1b collected at company Garden were reported. Dataset 1a was collected as structured interviews scoping the integration between product design and manufacturing by identifying working methods and tools, including knowledge assets. Dataset 1b included both structured interviews and an interactive study observing what assets designers used to do specific tasks, targeting the use of formal and informal design assets. Document analysis of different documentation as process charts and Design Guidelines was also a part of the data collection, where the

characteristics of different guidelines were analyzed. A summary of the data collection is presented in Table1.

Table 1. Data collection. Study 1a and 1b are reported in [8].

Study	Company	Interviews	Workshops	Demonstrations/Observations
Study 1a	Garden	10	-	-
Study 1b	Garden	5	1	4
Study 1c	Garden	4	1	3
Study 2	House	8	1	6

The data collection started with a general survey of knowledge reuse and development in the company, followed by specific questions targeted at identifying Assets used by different groups of staff. Study 1a included respondents from different departments, aiming at identifying specific challenges regarding interaction between manufacturing and design, to identify available support and processes, and to suggest improvements. Study 1b included respondents from one department of mechanical design and started with interviews to identify questions and gaps between what assets/resources that exists and what resource that are actually used. The respondents were design engineers, and the data was used for formulating the tasks for the subsequent demonstrations/observations. In this phase, also one process manager was interviewed to get an understanding on how guidelines and lessons learned are developed and maintained.

Study 1b involved two junior designers with less than 2 years' work experience, and two senior designers with over 20 years' experience. Study 1c involved Lead Engineers, e.g., senior designers that were responsible for the design of a whole product or product line. The respondents had a wide difference in experiences, thereby making the support needed for different experience levels more evident. In the data collection, document analysis of different Design Guidelines was included, and the content and characteristics of different guidelines were analyzed.

The engineers were observed when performing tasks needed to answer the questions presented in Table 2, that were identified in Study 1a:

Table 2. Questions at company Garden

Task	Study 1b: Design engineers	Study 1c: Lead engineers
1	How do you start to design a part in a new product?	You have been assigned as the lead engineer for a new, innovative product line. How do you start? What is the input? What assets do you use in the beginning?
2	What assets do you use to select a suitable screw for your part?	How do you control the product architecture and variants? What assets do you use?
3	What assets do you use to design a screw boss for your part?	What production reviews are done in the Advanced Engineering and Pre study phases?
4	What assets do you use to design a "Groove and tongue interface" between two parts?	What assets are used in Design for X (Assembly, Manufacturing etc.)?

Study 2 was a mirror of Study 1, conducted at the industrial house building company. Initially, data was collected through structured interviews, targeting working methods and tools, with the purpose to build understanding of how the company operates and to formulate tasks for the observation sessions. Here, six design engineers working in three different phases of industrial house building were observed solving tasks with the same

characteristics as in Study 1b. The respondents were selected by their manager to provide a mix of gender and experience with one junior and one senior designer per development phase. In this case, the junior designers had less than 2 years' work experience, and the senior designers all had over 10 years' experience. The questions that triggered the observed tasks are presented in Table 3.

Table 3. Questions at company House.

Task	Study 2: Design engineers
1	How do you start to design a new panel element connecting a "B4" standard joist with a sawtooth roof? What assets do you use?
2	How do you design installations in the "B4" standard joist. What assets do you use?
3	How do you ensure water runoff from the roof? What assets do you use?
4	How do you ensure that installations that cross the fire cell limit meet the fire safety requirements and that fire does not spread between the roofs? What assets do you use?

A limitation of the data collection in the studies was that development of software and electronic hardware were not included.

3. Results from the observations

Both companies have well defined and mature product development processes that can be characterized as incremental, based on phases and milestones. Their products have been refined and evolved over product generations with few introductions of disruptive technology. In the early phases of development, the product management of the companies define the market requirements and also the planned product variants, but none of the companies has formal method- or tool support for how to create and differentiate the planned product variants.

Both companies have different personnel for concept/architecture development and product development/building design. After the concept development phase, important knowledge and information may be lost in the hand-over of the project between stakeholders, since the companies has personnel scattered around different departments and development sites.

The companies have several production lines, mixing automatic and manual sequences, but an industrial house building line is substantially larger and has a longer takt time. Company House also has one extra manufacturing step, i.e., the final assembly of the house at the construction site, however, this is not included in the study.

3.1. Characteristics of Company House

Company House is operating on the residential market with design-build contracts, offering both single-family and multi-family houses. The product architecture is based on a flexible modular system and the different variants are defined by the technical platform, constraining what components can be designed and combined to fit the well-established production lines without extensive changes. New products and technologies affecting the manufacturing line are evaluated carefully before the introduction to avoid compromising the technical platform and the product architecture of the existing variants.

3.2. Characteristics of Company Garden

Company Garden is an Original Equipment Manufacturer of outdoor products for forest, park, and garden care, with factories and development sites around the world. The company is pressured by its competitors to both shorten the development lead times and lower the production costs. The company is therefore striving to improve its efficiency and is aiming to expand its product platform to increase the interchangeability of technical solutions between brands and markets. Moreover, the products are highly optimized, and the physical parts often realize several functions, in an integral product architecture.

3.3. Comparison of formal design assets

The two case companies have several types of formal design assets as summarized in table 4: The formal use of the asset was classified from 1 to 3, where "1" implies that it is documented and used on individual basis. "2" implies that the development process prescribes that it should be documented and used and that there is a template and/or repository for the asset. A "3" implies that there is an appointed person/team/role that is responsible for managing the asset and that the process prescribes when and how it should be used. The values are rounded estimates for all observations and presented in Table 4.

Table 4. Use of formal design assets at the two companies.

Type of asset	Description	Garden	House
Product realization process	Processes, checklists, and documentation to manage the product realization processes, often divided into distinct phases and milestones.	3	3
Lessons Learned-Project	Learnings from projects, focusing on improvement of the design process. Often adding new tasks in subsequent projects.	3	1
Lessons Learned - Product	Learnings from projects, focusing on "best practice" for certain design tasks or good design examples, arranged around specific parts.	2	-
Design guidelines	Guidelines that reason around how specific components or products could be designed	2	1
Design standards	Design standards specify how specific components or products should be designed	-	3
Test Standards during development	Test procedures conducted to assure the performance of new products under development	3	1
Modular components	Modular components are individual parts or subsystems that can be combined in different ways to create different products.	-	3
Reference architectures	These are templates that provide a standard structure and layout for products in a particular discipline. By developing a reference architecture, companies can	1	3

	ensure that their products are consistent and aligned with company- and external standards.		
Standardized interfaces	Standardized interfaces are a set of rules and protocols that define how different components or software are connected/communicate with each other.	1	2
CAD – Layout/ product architecture	Prepared CAD models containing objects that facilitate the layout and architecture of a complete product, such as references to major systems and parts	1	2
CAD Component libraries	These are collections of reusable components that can be used across different products and projects. By developing and maintaining a library of components, companies can reduce the time and effort required to develop new products.	1	3
Prepared Simulation models	Prepared Simulation models are pre-defined for reuse under standard conditions to predict the behavior of a system or product e.g., virtual testing.	3	1

3.4. Comparison of informal design assets

The case companies used several types of informal support that cannot be characterized as formal design assets. Substantial effort was used to seek information though personal communication. Besides communication with colleagues at the department, discussion with structural engineers, test facilities, suppliers and with the production department was a common way to get feedback on emerging designs. The use of an asset is classified differently from the table above. In this case, 1 means that it is used on individual basis and a 3 that it is used by most respondents. The values are rounded estimates for all observations and presented in Table 5.

Table 5. Informal design assets at the two companies.

Type of asset	Description	Garden	House
Previous CAD models	Reusing geometry from corresponding parts of the previous product generation as informal templates for new designs.	3	2
Previous physical parts	The corresponding physical parts used in the of the previous designs is used to get a hands-on experience of the emerging design.	2	1
Personal communication	Feedback/guidance on emerging designs through meetings, colleagues, team members, test personnel, construction site or others.	3	3
External information	Web searches, Supplier documentation etc.	3	3

4. Analysis and Discussion

Reflecting on the use of formal assets as presented in Table 4, it is evident that there is a significant difference between the degree of formalization of the assets that are used at the two companies. Both companies have similar types of design assets, but in most cases, they are used to a different extent. Some assets that are crucial in one company are not managed in the other. As an example, Company House has no formal process for how to collect and reuse learnings from projects, but still work with Design Standards that specify how specific components or features should be designed. Another mechanism is therefore used to collect information and knowledge for updating and maintaining the standard repository, which was not revealed in the study. Company Garden, on the other hand, hardly uses Design Standards but has well managed processes for both Lessons learned and Design Guidelines.

The reason that the companies use their formal assets differently may also lay in the way the companies are organized and the nature of their products. In both companies, the use of specific design assets is connected to the role and the experience of the user (junior or senior). The different application of assets, however, also depends on that the companies have developed different types/ classes of assets, such as a modular system. Company Garden has an integral product architecture where the parts often realize several functions, that are not suitable for embodiment into specific modules, as seen in table 4. Moreover, the character of the products and production system also limits how physical parts can be reused between product generations and product families.

Company House, on the other hand, has arranged its whole operations around their technical platform /modular system. Most houses are designed for a specific customer and the company can quickly configure new variants that are within the limits of their technical platform but are less flexible when it comes to introducing new modules that requires changes to the production system.

The use of informal assets (Table 5) is quite similar between the companies, and the employees use informal assets to a high degree. Personal communication is here considered as an asset since it is an important knowledge transfer mechanism that requires an investment in good relations between the involved parties. In both companies, CAD-geometry from corresponding parts of the previous product generation is reused as informal templates for new designs. One respondent, however, commented on this practice of reusing CAD-geometry as “inheriting mistakes”. It is therefore desirable to improve and generalize these informal assets into design guidelines or standards to successfully include these as a part of the platform.

To answer the question if there are any core design assets that may be generally valid in both disciplines, the results show similarities between the two companies. However, based on the results, it is not possible to compile a generic list of “best practice” to guide practitioners what assets to develop and formalize into platform elements in a generic context. A straightforward example of a formalized asset used in both disciplines are their well-defined product realization processes. The quality of an asset has been reported as one of the factors that determines if it will be used or not, but in the case of formalized development processes, these are mandatory in most mature companies, regardless of the quality/efficiency of the asset (process) or how well the employees deploy it.

5. Conclusion

The presented paper is an extension of the research in source [8] studying the assets used at a mechanical design department. The objective was to compare the use of assets in another discipline, industrial house building, to clarify if there were core design assets that may be generally valid as platform elements in product development companies. The earlier study [8] identified several types of design assets, and reported that design engineers used both formal and informal assets, but concluded that they often preferred to seek information though personal communication rather than using formal documents and guidelines. The study also stated that there were differences between how senior and junior engineers used the assets. Junior designers used formal assets to a high degree, and also relied more on discussions with the closest colleagues than senior engineers. The senior relied mainly on their wider palette of informal assets and utilized a broader network of colleagues at other departments and at suppliers.

The present study clarified that the companies had similar types of assets, but to a different degree of formalization depending on the different product types and production systems. Moreover, at both companies, the employees used informal assets to a high degree, and the difference between what types of assets that junior and senior designers used were similar. However, a generic set of assets suitable as platform elements could not be identified in the study.

Future studies will aim at developing a framework to identify potential platform elements based on the specific design assets that exist in a company. The next step is to clarify the factors that determines what types of assets that should be considered as platform elements in different contexts.

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