Platforms for Enabling Flexibility at Two Construction Companies

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Abstract –

Product platforms have proven to be an effective means for many industries, seeking to achieve front end variety based on back end commonality. Modular design with standardised interfaces, enabling reuse of components in derivative products over time, has been a success factor for i.e. automotive industry and other types of industries operating in a modify-to-order or configure-to-order supply chain. For construction companies who operate in an engineer-to-order, or even design-to-order supply chain, extensive and changing customer requirements must be managed and full product standardisation could, therefore, affect a company's market offer adversely depending on its market segmentation. In previous research, one key finding is that construction companies tending to a wider market segment could focus on standardising processes rather than products. Furthermore, previous research highlight the notion of process platforms as a subset within product family design, albeit, little research focus has been given to process platforms for construction companies. In this study, two construction companies are studied with the aim to describe their means for enabling a flexible product offer whilst maintaining a platform strategy. Findings shows that both companies have process platforms with explicit and implicit relations to product realisation and that standardised processes are a vital part in offering end product flexibility whilst maintaining a platform strategy. This study identifies the need for additional research to elaborate and generalise the relation between process platforms and product flexibility, and implies that theory linked to product platforms need to be developed in order to incorporate construction companies where full product standardisation is in conflict with their production strategy.

Keywords –

Industrialised house-building; Process platform; Process standardisation; Platform strategy

1 Introduction

Industrialisation in construction has gained attention and traction from both academia and construction companies [1]. By moving value-adding activities upstream in the construction value chain, through pre-engineering and off-site construction, a trade-off between flexibility and productivity can be evaluated and used to target specific customer segments [2]. An orientation towards increased industrialisation is often, for the Swedish market, motivated in research through low productivity for the construction industry in comparison with more traditional manufacturing industries [3] and therefore often proposed approaches have been suggested by glancing towards the same successful strategies which has been applicable for traditional manufacturing, e.g. automotive industry. Applicability of lean principles for industrialised house-building [4], [5] or adoption of product platforms has been among notable examples of such strategies, where the latter forms the basis for this paper.

A widely used description of a product platform is presented by Robertson & Ulrich [6] which defines it as *'the collection of assets that are shared by a set of products'* and that these assets can be divided into *components*, *processes*, *knowledge* and *people and relationship*. In essence, product platforms strive to offer customers products which exhibit front-end variety based on back-end commonalities, by altering the process of product development. The leap is from the development of unique one-off products to platforms where a family containing several variants shares some common assets. Through modularisation, i.e. dividing products into modules or chunks containing related components and standardising interfaces between these, the automotive industry has been and remain to be successful [7]. Jiao et al. [8] presented '*a holistic view of product family design and development'* based on axiomatic design [9] in which several platforms in between different domains accounts for all fundamental issues related to product realisation from a client perspective (front-end) to the entire supply chain (back-end). In related work, Jiao et al. [10] define

a process platform in a generic hierarchical structure as the combination of machining- and assembly operations required in combination with a corresponding product structure (raw material, parts, and subassemblies) to formalise an end product. Most of the subsequent studies including process platforms have adopted this view on its relation to explicit product realisation [11]–[13]. However, it is the authors' standpoint that a formally defined solution space for product realisation requires confined boundaries for the product definition, which is contradictive for construction companies which offer product flexibility through open design processes.

In a multiple case study by Johnsson [14], empirical findings were used to suggest that mainly companies *'who integrate the supply chain towards a specific market segment benefit fully from the platform concept'*, i.e. companies with a higher degree of product standardisation. Companies with a wider scope of customer segmentation could, whilst maintaining a platform strategy, focus on standardising processes rather than products. It is important to distinguish between two different types of processes and how they are being used in this paper, those with explicit or implicit relation to product realisation.

- **Explicit processes:** Machining operations, assembly operations, raw material treatment with direct connection to product realisation [10]
- **Implicit processes:** An umbrella-term for processes which indirectly aides product realisation, e.g. open design work, setup/preparation in production or following routines when managing information.

The purpose of this study is twofold, firstly to describe platforms at two construction companies with production strategies aimed at enabling flexible products. Secondly to discuss, whether the theoretical notion of process platforms, found in literature today, are applicable for house-builders where full product standardisation conflicts with their production strategy.

2 Related research

2.1 Distinguished characteristics of different construction companies

Construction companies can be differentiated according to their level of industrialisation, which partly depends on their use of pre-engineered solutions [14] and production methods [2]. A different but related take is the dividing on companies depending on how they manage their supply chain [15]. As buildings are rarely pre-produced and kept in stock based on a forecast, and product realisation often requires an engineering design phase to adapt to regulations or spatial conditions, the predominant production strategy for construction can be characterised as engineer-to-order [14]. Johnsson (ibid.) elaborates on this and distinguishes between different production strategies within the engineer-to-order context depending on the level of pre-engineering in the design phase. Engineer-to-stock represents a fully predefined product and design-to-order offers product flexibility through an open design process. Adapt-to-order is a middle ground between these two. This determines in what stage the customer enters where a fully defined engineer-to-stock-solution entails later client entrance.

There are various contextual interpretations available for the specifics related to the construction industry on this matter. Winch [16] proposes concept-to-order and design-to-order to distinguish between the difference visible between two standard forms of procurement, namely design-build (CTO) and design-bid-build (DTO). Segerstedt & Olofsson [15] differentiates between different production strategies based on the level of completed specifications upon client entrance, where building systems within engineer-to-order bases the pre-set specifications on current building codes and local regulations, leading to high flexibility in the end product. When buildings instead are completely specified upon client entrance, all that is left is for the client to select a variant. Regardless of terminology, the different strategies can be linked to the level of pre-engineering applied in product definition and realisation.

2.2 Platform use in construction

In this paper, platform use can be interpreted as an agreed upon strategy applied by a company, to gather, distribute and reuse pre-engineered solutions and standardised processes as well as actively working with managing, maintaining and utilising said solutions and processes. A prerequisite is that product or component pre-definition exists to some degree within the platform.

Applied to construction, the majority of studies available on platform development have inherited their product orientation from traditional manufacturing, focusing on either confining or defining the product within boundaries set by a product platform. Veenstra et al. [17] introduce a methodology for developing product platforms in the specific context of house-building in which a framework for defining a module based product architecture is presented. Jensen et al. [18], [19] similarly approach the construction industry by modularising the building system. In their work, different module variations with standardised interfaces and parameterised variables, i.e. length, width etc., produce an allowed solution space in which the product can be designed through a configurator.

In a case study, Bonev et al. [20] applies the holistic approach to product family design as suggested by Jiao

et al. [8] on a precast manufacturer and noted the interrelationship between reuse and commonality along the entire value chain. Furthermore, they highlight product platform deployment as a mean to retain flexibility whilst moving towards mass customisation, but argue simultaneously that a higher degree of predefinition during the engineering phase is inevitable for platform benefits. Thuesen et al. [21] made a study on success factors from a German housing platform and highlighted the importance of continuous learning, repetition, and standardisation through *'[…] long-term incremental and systematic innovation with a clear separation between the continuous development of and the production based on the platform'*. Standardisation of different house types available for the customer was particularly stressed.

construction company. The platforms are described as the collection of blueprints with technical solutions and documents or procedural descriptions aimed at guiding the design and production phases. Lessing [1] reinterprets the traditional platform concept and separates for industrialised house-builders between a technical platform and a process platform. Figure 1 depicts how the continuous interplay between both platforms are used to support a stream of projects as well as how experience is continuously fed back to each platform.

Even though no empirical data is presented to verify or in practice identify his exemplified process platform, it is proposed to contain processes beyond assembly operations or raw material treatment, i.e. beyond explicit product realisation. In his licentiate thesis, the process platform consists of modules where ICT (Information

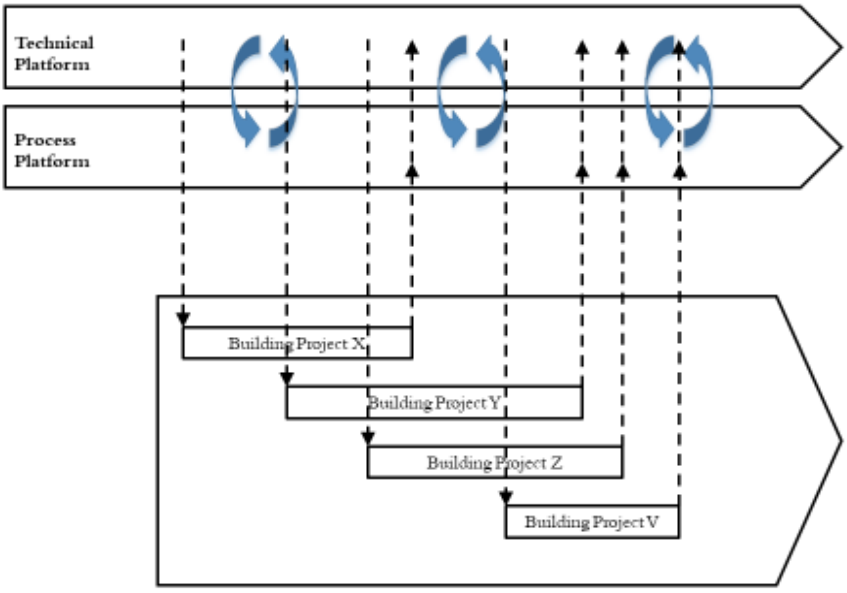

Figure 1. Process model for industrialised house building [1]

Jansson et al. [22] acknowledge the specific conditions visible for ETO construction companies in terms of managing the balance between commonalities and distinctiveness. Jansson et al. (ibid.) propose a platform model with support methods to manage distinctive project parameters. That case study identified all product platform assets described by Robertson and Ulrich [6], but the presented support methods for implicit product realisation focuses mainly on the design phase.

According to Styhre & Gluch [23], the platform serves as an object to facilitate knowledge sharing and accumulation. This knowledge management perspective on platforms is presented through a case study in a large

and Communication Technology), team collaboration and routines for integrating logistics for a reliable flow of material are some examples. In reviewing these platform-related studies applied for construction, the production process and its interrelatedness to a defined product are of essence when process platforms are addressed. Many elude the flexibility required or desired by certain actors in terms of their ability to adapt their end product after customer requirements, and there is a scarcity of studies which elaborates on how the process platform mediate end product flexibility.

3 Research approach

To meet the purpose addressed in this paper, two companies have been studied. The research was grounded in a literature review on process platforms and platform use in construction where the literature review highlighted the gap in the reviewed body of previous research which motivated the purpose of the study.

To collect empirical data, two different methods were used; interviews and study of archival material. Interviews were conducted with a representative person of each company who has insight and responsibility for the use and development of platforms. Each interview lasted approximately one hour and questions posed were mostly concise, focusing on facts linked to each company's product offer and platforms rather than opinions. Interviews were semi-structured, where follow-up questions were posed for clarity when deemed appropriate. Interviews were recorded and later transcribed verbatim for the analysis. Both authors participated during both interviews and were later responsible for transcribing one interview each. The archival material consisted of access to one of the participating company's (Alpha) intranet, where all documentation in regards to their platform is stored.

The descriptions of each company provided in the following section of this paper are based on empirical data and the idea is to provide insights into what kind of strategy each company applies, i.e. what their product offer is, as well as information regarding their platforms with particular focus on their process platforms. The empirical data was also used to identify explicit and implicit processes according to the definitions previously provided in this paper.

4 Companies Alpha and Beta

Two different companies has been examined, Alpha and Beta. Alpha is a Swedish multinational construction company that has construction projects in all main areas, including residential buildings, commercial buildings, roads, bridges, tunnels and more. The company is among the top biggest construction companies in Sweden and they are organised in regions as separated divisions all over the country.

Beta is an industrialised house-builder who uses modular technique to produce multi-family dwellings for the Swedish market. The company is mid-sized, family owned and an important actor on the market for multi-family dwellings as well as one of the leading actors applying industrialised methods in production.

Both companies apply industrialised methods to various degrees with the common traits that they both have adopted a platform strategy and they both gain a competitive advantage in offering product flexibility to their customers, albeit to various degrees in comparison to one and another.

4.1 Alpha

Alpha is what can be considered as a traditional construction company. They do both general contracts, turnkey contracts and project developments starting with a concept. Alphas main selling point is that they can develop and produce almost any kind of structure that the client has in mind. Alpha has almost no repetition of projects. In offering this variety, it is difficult to define Alpha as a single entity. This study is limited to the part of Alpha affiliated with design and production of multi-family dwellings.

4.1.1 Strategy

Alpha's main production strategy is either concept-to-order or design-to-order depending on contractual agreements (design-build respectively design-bid-build) [16].

For concept-to-order, Alpha can either procure an architect or do design in-house, depending on the client's wishes. Structural design is often performed in-house by Alpha's engineers, often in concrete or steel as Alpha is more experienced with these materials. Remaining disciplines, e.g. HVAC engineering is often procured. The construction process follows a traditional flow with tendering, design and construction. The projects are treated like small companies within the company. The design and engineering department work with several projects at one time. Construction is either done completely on-site or in combination with prefabricated walls or slabs produced off-site. Each project usually procures multiple subcontractors to work at the construction site.

Alpha previously offered a platform-based concept containing multi-family dwellings with a high degree of pre-engineering. Late adaptation to customer requirements and an inability to reduce production costs rendered the business unsuccessful and the project was cancelled. Alpha now has an affiliated subsidiary that offers platform-based engineer-to-stock concepts for housing.

To offer a very flexible product in a resource effective way, Alpha operates two main platforms on different abstraction levels. MP (Managing Platform), for managing a full project life-cycle from tendering to the maintenance phase, and CP (Construction Platform), for the design and construction phase.

4.1.2 Process platform

The main difference between the two used platforms is that the MP (Managing Platform) contains only support for the process of pursuing and controlling a project, while the CP (Construction platform) contains both

support for the design process and the technical solutions and decisions. Both platforms are easily accessible for all employees on the intranet home page.

The MP is used for all projects regardless of size and type, and supports the process of pursuing a project, but has no connection to technical components at all. The MP is divided into two parts, where the first part is aimed for upper management and is the same for all divisions. The second part is aimed at site managers downwards to all the white-collar worker positions and is division specific. The MP consists of mostly different kind of text documents, checklists, time planning sheets, and descriptions. It is organised around the different phases, specifying all the required activities, whose responsibility it is to realise them, comments, and supporting materials.

During the engineering process, the MP defines standardised steps mostly consisting of meetings where limits and responsibilities for the project are to be decided. There are many templates for meeting agendas, how the organisation and positions in the project should be set up, when and how important economic decisions should be made, what risks to consider and when to consider them, and how the engineering phase should support a later safe work environment in production. For the production phase, the MP is focused on quality control, what to consider in different situations, how and what to check to ensure that the projects are running well, and make sure laws, certifications and standards are followed.

The CP consists of descriptions, checklists, drawings, films and documents for both the design phase and construction phase. For the design phase, the CP consists of a collection of conceptual technical solutions. For each technical solution, there is a document describing the components and what to consider for each of them, and advice on how to avoid risks and mistakes that will lead to a lower quality product. Some of the advice is more conceptual, while some are detailed with given values or solutions. The conceptual technical solutions for different parts of a building are referred to as "standard construction parts", and most technical solutions prescribed by engineers are variations of these. There are ready made-drawings of standard construction parts complete with text for production that can be imported to a project drawing.

The design process is supported by the CP where there are predefined concept solutions that can either be used as they are or tweaked to fit the current project. These predefined concepts act as a base for the engineers to work from, but they are free to create their own solutions if it better fits their project. The CP also contains a great number of documents describing what is important to consider and why for different parts and concepts of a building, on both higher abstraction levels like the layers in a wall, and more concrete ones like the required measurements for garages. The designer also has access to documents that describe risks with different options and what can be considered to minimise these.

The CP has a dedicated chapter for standardised productions methods, that contains pictures, drawings, documents, links to manufacturers and instructional films. There are links between the standard construction parts and their corresponding standard construction method. For each construction method there are lists of prerequisites, "tips and tricks" from other employees, possibilities and risks described. The production methods described give room for adaptations to the project and describe how to create a quality structure rather than a specific one.

4.2 Beta

Beta integrates sales, design, manufacturing and on-site assembly within the firm as different departments and takes full client responsibility from client entrance to a finished building. Modules are manufactured off-site in one of two production plants and shipped to the construction site where they are assembled together. Both production plants have different production lines for wall elements and slabs which are later combined into modules; sequent work (i.e. electricity, HVAC, mounting etc.) is carried out by a skilled workforce in a one-piece takted flow.

Beta has a technical product related platform consisting of templates in their CAD-software with predefined technical solutions for e.g. planar elements or joints between two elements. Complementing the technical platform, there is linked related information for product realisation such as assembly operations, checklists etc. which forms a part of their process platform.

4.2.1 Strategy

Beta competes regularly for tenders with traditional contractors within their product offer, and balances between platform standardisation and product flexibility as one of their competitive advantages. Beta produces multi-family dwellings (tenancy and condominiums), hotels and student housing, but no single-family houses or row houses. Element standardisation from a parts library within a technical platform forms their basis for enabling off-site production in a factory setting. Repetitiveness in production must be high enough to enable specific workstations for each particular operation to be performed. This is especially important for the structural system forming the modules, i.e. wall elements and slabs. Each section of the production line is designed for a particular operational procedure, e.g. mounting layers of plasterboards, insulating etc. This can be done manually by a skilled workforce or fully automated by

machines, depending on where in the line or in what factory the operation takes place.

On the sequent volume line, after elements have been assembled to modules, work-tasks vary more according to the specifics of each module. Even though planar elements are highly standardised between different projects, compositional combinations of different modules are customised for each project. In that sense, the modules are not standardised objects, apart from in a few pre-defined concepts aimed at e.g. student housing which can be offered to clients. In doing so, Beta fulfils customer needs and requirements by offering product flexibility in regard to floor layout or module features. This requires a somewhat traditional design process where both in-house (e.g. structural engineers) and procured personnel (e.g. HVAC engineers) collaborate.

Beta operates mainly with an adapt-to-order engineering strategy based on their level of predefinition in their structural building system, which can be used to configure unique modules. The level of platform adaptation varies between and within different projects where certain project related subparts, e.g. a detached but adjacent building for laundry could be engineered design-to-order in accordance with an open design process based on customer requirements together with current norms and standards. Engineer-to-stock solutions, as in the case with conceptualised solutions for student housing exists as well.

Beta has *'preferred solutions'* in different aspects of defining or realising a building in which they know, based on experience, what works well and what doesn't. In operating a platform strategy, there are some *'non-negotiable'* limitations for product flexibility at Beta, i.e. the thickness on a slab separating two storeys, affecting the structural system.

4.2.2 Process platform

To alleviate the constraints inflicted by product standardisation in the technical platform, Beta has a process platform. Standardised processes for product realisation are mainly communicated through Standard Operating Sheets (SOS), but they could be any type of documentation which successfully can be used to illustrate how a certain task should be carried out, e.g. through a checklist. The collection of documentation capturing these standardised processes constitute the basis for Beta's process platform. Some SOS explain explicitly how to conduct a specific task, for example through a step by step guide with associated images, which are needed to perform a specific work operation.

There is however a large number of standardised processes which has no explicit connection to a specific product, these can instead have implicit relations to the realisation of a product. This can be exemplified by describing Beta's design process, which is aided by a tailored software system for visual planning. The broken-down processes needed to carry out a building design is to a large extent standardised and rigorously monitored in a system as the design progresses. What documentation or activity is required, who should deliver or perform it, when should it be delivered or performed and who is the recipient. These are formalised questions which are gradually being answered during the design process. The majority of all sub-processes in the design process are the same in each project, regardless of which building project is in focus.

There are also standardised processes for different departments at Beta, including supporting functions such as sales, logistics, and purchasing. The process of drafting a standardised process is in itself a standardised process, which is firmly grounded within the collegial community as they are regularly formed and updated.

The complete collection of process documentation for all departments is stored on a server in which the head of each department has the responsibility to update and maintain its own processes. According to the company respondent on the managerial level, both the technical platform and the process platform are equally important. Though that may be a view not entirely shared between everybody at Beta, it gives an insight into the perceived value of working with standardisation on both product and process level.

5 Analysis and discussion

The limited amount of empirical data collected should be assessed alongside the sparsely explored subject in focus of this research. Being a study with a qualitative analysis, the purpose is not to claim generalisability, but rather to provide insights into the subject at focus by providing experiences from these two construction companies. The possibility to access and study archival material in form of documentation of Alpha's process platform was a strength for the validity of the findings. It provided an additional perspective on the platform description by enabling the authors to examine the content and structure for themselves. On the other side, those insights could not be used to draw any conclusions regarding how the platform is actually implemented in projects. The access was however important to avoid misinterpretations during and after the interview, as the platform concept as discussed in research literature, was quite unfamiliar to the respondent at Alpha. No such clearly compiled documentation was available for the authors at case company Beta, where the respondent on the other hand is very knowledgeable in the field of product platforms from both a practical and a theoretical perspective.

Platforms at Alpha differs from the more traditional notion of product platforms mainly aimed at

manufacturing industries in that it contains fewer defined products and more processes. The concept of e.g. product family development is not aimed or well suited for describing platform use in a company like Alpha. According to Jiao et al. [8], the concept even implies a make-to-order or assemble-to-order production strategy. Alpha strives however towards increasing platform utilisation in which appropriate theoretical models could be useful.

At Beta, platform use is already firmly grounded within the company, and considering their level of component pre-engineering in their structural system and their production method, both a technical platform and a process platform forms a vital part of their knowledge base. Nevertheless, their use of open design processes to accommodate customer needs outside the boundaries of their platforms on a project basis is not sufficiently represented within the reviewed frame of platform-related theory.

At both companies, processes not explicitly related to the realisation of a specific product were identified. More than so, these were a formalised part of each company's platform. Probably most companies have formalised and standardised processes which could be argued to have an implicit relation to realising products, regardless of production strategy or type of business, for that matter. The question is how the theoretical notion of product platforms should incorporate or account for this? This study does not answer that question, but the results suggest that standardising processes with implicit relations to product realisation could be an important aspect of enabling product flexibility whilst maintaining a platform strategy. Product platforms is a strategy originally intended for businesses with fewer open design processes on a project basis compared to the companies Alpha and Beta. This suggests that theoretical frameworks, which accurately address these aspects, needs to be developed to fit within the existing body of platform-related theory.

At both companies, we saw both an interplay between a technical platform and a process platform as well as how parts from both platforms fed the stream of ongoing projects. This interplay was for instance manifested at Alpha when links between a pre-engineered part (e.g. a wall element) and associated documentation (e.g. checklists etc.) were established. At Beta the same interplay could be seen through the link between a pre-engineered part and the collection of associated SOS. A proposed update to the process model presented by Lessing [1] is that the process platform, not just the technical platform, is feeding each project. This is specifically highlighted and presented in Figure 2. The revised figure does not deepen the insights regarding the actual interplay between a technical and a process platform but it stresses the process platform's role in individual projects as important.

The platform model proposed by Jansson et al. [22] could also be used to incorporate findings presented in this paper, the implicit processes are arguably acting as support methods in product realisation at the two case companies. However, as a platform model, it too lacks the required granularity needed to depict how pre-engineered solutions and standardised processes actually interplay with each other and fit together within the

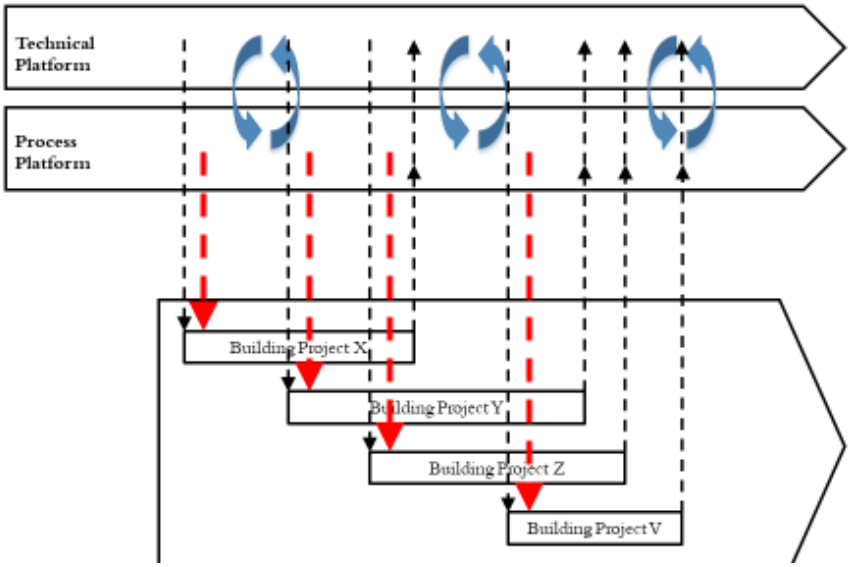

Figure 2. Process model for industrialised house building, revised from [1]

platform. Therefore, further studies are needed to elaborate on this interplay and provide data to identify what mechanisms are put to use within the platform as all subsets within a platform work together to offer flexibility whilst maintaining benefits from applying a platform strategy. An updated platform model should differentiate between mechanisms which are completely or partially dependent on open design processes from those mechanisms which are needed to handle pre-engineered solutions as this study suggest that this level of granularity is needed to establish the relevant processes, implicit and explicit, needed to accommodate product flexibility. Then it can be further developed and concretised to form the basis for a platform strategy better suited to companies like particularly Alpha.

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