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SEARCH QUESTIONS

Symbiotechniques and architectures of production 4.1

Open Process Ecosystems

July 2018

Our twelve search topics:

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10. Walking
11. To architecture
12. Unschooling

OPEN PROCESS ECOSYSTEMS. BEYOND PRODUCT PLATFORMS FOR MULTI-STOREY HABITATS DESIGN AND MANUFACTURING.

Open Process Ecosystems could be a proper systematization framework for an efficient, ecological and successful tall timber habitats design and manufacturing enterprise.

Symbiotechniques and architectures of production 4.1

How can we develop techniques and means of production that improve and don´t destroy life?

At Aixopluc we research techniques that don't just adapt the Earth to our limitations and abilities, but that are a means to improve the biosphere's diversity and complexity -while helping us become more adaptable and resilient.

From parasites to symbiotes.

So the whole biotope can make it.

SEARCH QUESTIONS

As a consequence of our search as architects, we also produce knowledge made of words -written and spoken. Words are very different from wood or clay, sunlight or rain, or the bodies and skills of builders. They demand their own abilities, techniques and care. They help us to organise, formulate and share this knowledge. Our own search revolves around twelve constant themes, things we don't have a definitive answer to yet, which we present here as questions. This knowledge is not just a by-product of our activity, but rather an instrumental part that develops simultaneously and is imbricated in building.

Abstract

There is a global interest in large-scale construction and development companies in the application of Product Platforms to achieve a repeatable industrialized house-building system. This paper analyzes and evaluates several Product Platform aspects -modularity, commonality, scalability, resilience, adaptability, flexibility- in light of the particular challenges of multi-storey houses design and manufacturing. We identify and describe these challenges as: Inhabitable space and time. Site specific. Exposed to climate and weather. Lifespan and durability. Size and weight. The convergence of these variables is particular of architectural design discipline. The results show that the complex design needs and constraints of industrialized house-building are not fully covered by Product Platforms, and therefore a more suitable system architecture is needed.

Accordingly, in this paper we focus on the following questions: Which design and manufacturing processes can we develop in order to provide a better answer to the specific challenges of multi-storey housing production? How can a specific architectural design approach help to shape these processes?

After a comprehensive Product Platforms literature review, this paper introduces the original definition of Open Process Ecosystems as a suitable system architecture, which includes several Product Platforms qualities, but shifts from product to process, and from platform to ecosystem. Additionally, we inquire which parts of this Process Ecosystem work better by being open, welcoming as much heterogeneous and uncertain uses, components, agents and contexts as possible.

The paper concludes that Open Process Ecosystems could be a proper systematization framework for an efficient, ecological and successful multi-storey habitats design and manufacturing enterprise and indicates topics for future research.

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Keywords: open process ecosystems, product platforms, multi-storey housing, prefabrication, industry 4.0, applied architectural design research.

Introduction

This paper speculates on a new systematized approach to the design and manufacture of multi-storey habitats, by applying architectural design knowledge to the field of Product Platforms. Instead of mimicking other industries, it is necessary to start with a critical revision of state-of-the-art manufacturing processes. At a time of increasing disruption, as the internet-age fundamentally changes how businesses operate, it becomes important to understand which technologies will thrive and which will become obsolete. Technological change is further compounded by today's global context of increasing resource scarcity, climate change, and demographic change. Currently, traditional industry looks to the digitization of 'Industry 4.0' as a means of responding to these issues[1]. Construction has a long history of looking to manufacturing, for improved work methods, yet there remain certain peculiarities about construction that industrial methods struggle to address[2]. Though construction also looks to the principles of Industry 4.0 for improvements, these are framed through the lens of traditional industry. Instead we consider that construction should look through the principles of Industry 4.0 (fig. 1) and seek to adapt and transform them to respond to the peculiarities of construction, rather than further leveraging traditional industry's techniques.

Alongside this push to digitize industry, the benefits of a platform-based approach to customization and families of products is acknowledged. Companies are being faced with the challenge of providing diverse product ranges to the market with highly standardized production methods to suit automation[3]. It is in this context that a detailed study of the potential applications of Product Platforms in the construction industry is of interest, especially to speculate on what the future of platform approaches will be.

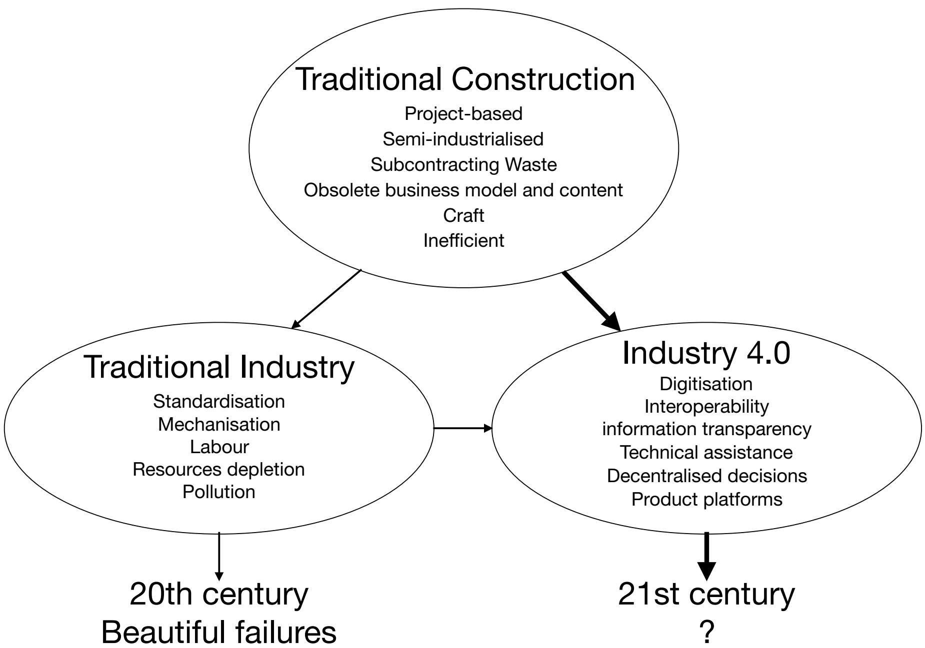

Figure 1. Construction industry current direction.

[1] Germany Trade & Investment, "Industrie 4.0," November 17, 2016.
[2] R Vrijhoef and Lauri Koskela, "Revisiting the Three Peculiarities of Production in Construction," Lean Construction Theory, 2005, doi:10.1080/09613210110039266.
[3] Timothy W Simpson et al., Advances in Product Family and Product Platform Design, (New York, NY: Springer Science & Business Media, 2014). p.201
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Frame of reference and literature review

Product Platforms emerged in industry in the final quarter of the twentieth century as a means for companies to gain design and manufacturing efficiency through the sharing of parts between products. Famous case studies have emerged, such as that of Black and Decker redesigning their range of tools around a single motor. In the 1970s, or the use of product families by automotive manufacturers, such as General Motors during the 1960s, that lead to the creation of platforms that run across large automotive conglomerates such as Volkswagen today[4].

By the 1990s, academics were studying the use of product platforms and their implications for increased manufacturing and design efficiency. Product platforms were first defined by David Robertson and Karl Ulrich, as a "collection of assets that are shared by a set of products"[5]. These assets take the form of physical components and relationships between people, as well as the processes involved in design and manufacture, and the knowledge that the business uses to undertake these processes[6]. Using these assets, Alvin P. Lehnerd and Marc H. Meyer determined that a "stream of derivative products [could] be efficiently created and launched", by taking advantage of the platform's ability to generate "commonality, compatibility, standardization or modularization" between product lines[7]. The product platform approach brought efficiency, flexibility, and responsiveness to the product design and manufacture process.

By the 2000s, the lessons of product platforms were being proposed for industrialized house building by Swedish researcher, Jerker Lessing[8]. Furthering this proposition, Gustav Jansson proposed design support methods, that allowed planning, collaboration, optimization, and iteration to occur to address the unique requirements of construction as opposed to manufacturing[9]. Swedish companies have led the commercial implementation of product platforms for house building, forming close relationships with the academy[10]. However, these efforts still present strong limitations in terms of lack of contextualization, obsolete apartment configurations, and overall architectural design innovation possibilities. As well as Jansson's process-based adaptation, research has also looked at their application in terms of the built product. Patrik Jensen investigated the application of their principles to the design of the built product through the use of software configuration tools[11]. While some research has considered the application of product platform logic to single-dwelling design and construction, the majority has had its focus on the multi-residential domain, where efficiency is enhanced by scale[12].

The diversity of usage of the term 'platform' in business has been noted[13]. While the use is profligate, when applied judiciously, the term refers to a specific logic of working method. This logic is defined by the above discussion of product platforms, which seek efficiency of process through the search for commonality in the pursuit of distinctiveness. This logic was furthered, by Annabelle Gawer, to extend beyond the 'internal' domain that creates physical entities from product platforms, to operate with a company's supply-chain, extending to create 'industry-wide' platforms that redefine a business' operations[14].

In the mid-1980s, Michael E. Porter established that value in business is generated by a value-chain, a definition that saw value created by agents in a linear, sequential manner[15]. However, it was in 1993 that James Moore first articulated a vision of businesses operating as an ecosystem, fundamentally altering how relationships exist, generate value, and drive innovation[16]. The personal computing industry of the 1990s began to develop complex business ecosystems[17]. However, the widespread adaptation of the concept has only recently occurred with the development of the internet-age redefining how business transactions are able to occur. Recently, Choudary, Parker, and Van Alystne termed traditional businesses as 'pipeline' entities, noting that future competitive advantage would be established by companies that were able to create and own a platform ecosystem that would attract participants[18]. Ville Eloranta and Taija Turunen contend that platform ecosystems are founded on three principles: connecting, sharing, and integrating[19]. From an architectural design perspective, these principles it would

4 Alvin P Lehnerd and Marc H Meyer, The Power of Product Platforms, (New York, NY: Simon and Schuster, 1997); Roland Marchand, "The Corporation Nobody Knew: Bruce Barton, Alfred Sloan, and the Founding of the General Motors 'Family'," Business History Review 65, no. 4 (1991): 825–75, doi:10.2307/3117266.
5 David Robertson and Karl Ulrich, "Planning for Product Platforms," Sloan School of Management 39, no. 4 (July 1998): 19–31. p.20
6 ibid.
7 Alvin P Lehnerd and Marc H Meyer, The Power of Product Platforms, (New York, NY: Simon and Schuster, 1997). p.7 & 2.
8 Jerker Lessing, "Industrialised House-Building: Concept and Processes" (Department of Construction Sciences, Lund University, 2006).
9 Gustav Jansson, "Platforms in Industrialised House-Building" (Luleå Technical University, 2013).
10 Duncan W Maxwell and Mathew Aitchison, "Lessons From Sweden: How Australia Can Learn From Swedish Industrialised Building," (2015 Modular and Offsite Construction Summit, Edmonton, Alberta, 2016), 190–97.
11 Patrik Jensen, "Configuration of Platform Architectures in Construction" (Luleå Technical University, 2014), http://ltu.diva-portal.org/smash/record.jsf?pid=diva2%3A999753&dswid=-5144#sthash.lB81L9eJ.dpbs.
12 Christian Thuesen and Lars Hvam, "Efficient on-Site Construction: Learning Points From a German Platform for Housing," Construction Innovation 11, no. 3 (2011): 338–55, doi:10.1108/14714171111149043; Gustav Jansson, Helena Johnsson, and Dan Engström, "Platform Use in Systems Building," Construction Management and Economics 32, no. 1 (February 2014): 70–82, doi:10.1080/01446193.2013.793376.
13 A H Kristjansson, T Jensen, and H P Hildre, "The Term Platform in the Context of a Product Developing Company," DS 32: Proceedings of 2004 International Design Conference, 2004.
14 Annabelle Gawer, "Bridging Differing Perspectives on Technological Platforms: Toward an Integrative Framework," Research Policy 43, no. 7 (September 1, 2014): 1239–49, doi:10.1016/j.respol.2014.03.006.
1985).

appear are conducive to increased design-value generation for building occupants, and are a key asset in the intricate and often chaotic supply-chain and procurement management of traditional construction companies.

Researchers have begun to propose that these platform ecosystems may emerge to co-ordinate construction contracts, potentially removing the role of a central contractor, instead replacing it with an industry-wide platform to which sub-contractors would interact, delivering value for the building's end-user[20]. Rather than limit the scope of a construction ecosystem to a specific professional perspective, or partial product platform that different actors in the construction industry might develop in isolation from each other (fig. 2), this paper builds on previous research to develop a methodological framework at the other end of the building industry spectrum. This view is based on a case where a single entity takes care of the whole development, design, manufacturing and on-site assembly process, and builds on an emerging body of research where we contend that construction ecosystems of the future should have design at the heart of their organization, providing a central, coordinating role to oversee and enhance value generation in designed interactions[21].

It is not clear whether emerging technologies will disrupt and replace construction companies. The particular characteristics of buildings, described in this paper, are a significant differential factor to other industry sectors. However, it is likely that construction companies that don't innovate their business model will be exposed to disruption. This vision for a shift from 20th century logics of prefabrication to a platform ecosystem, is especially relevant to the case of multi-residential projects due to their wide range of design and production inputs.

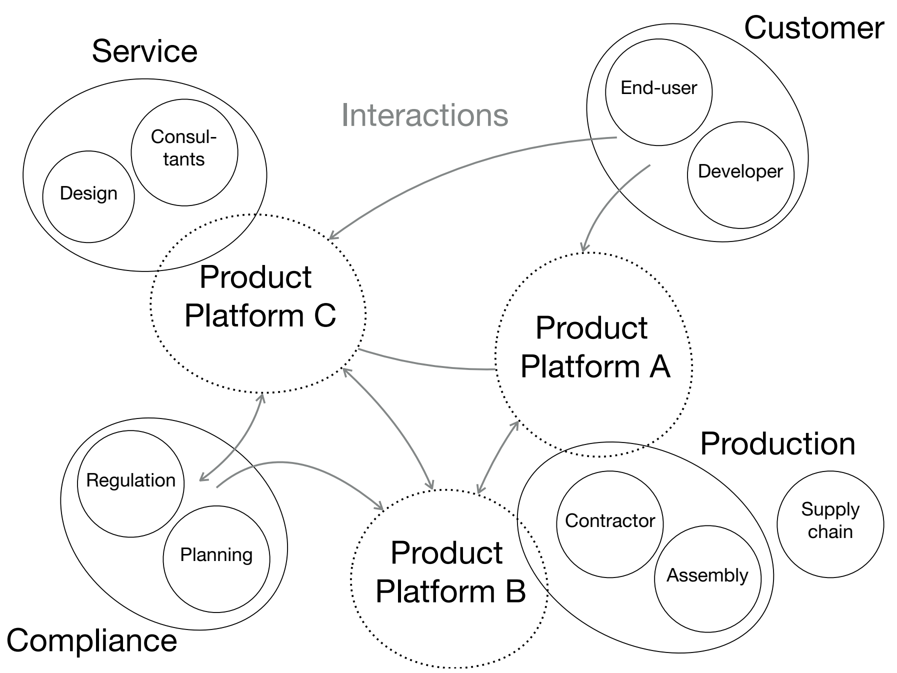

Figure 2. Diagram of current emerging isolated platforms in construction industry.

[15] Michael E Porter, Competitive Advantage, (The Free Press, 1985).Michael E Porter, Competitive Advantage, (The Free Press, 1985).
[16] James F Moore, "Predators and Prey: a New Ecology of Competition," Harvard Business Review 71, no. 3 (May 1, 1993): 75–86.
[17] A Gawer and M A Cusumano, "How Companies Become Platform Leaders," MIT Sloan Management Review 49, no. 2 (2008): 28–35.
[18] Sangeet Paul Choudary, Geoffrey G Parker, and Marshall Van Alystne, Platform Scale, (Platform Thinking Labs, 2015).
[19] Ville Eloranta and Taija Turunen, "Platforms in Service-Driven Manufacturing: Leveraging Complexity by Connecting, Sharing, and Integrating," Industrial Marketing Management 55, no. C (May 1, 2016): 178–86, doi:10.1016/j.indmarman.2015.10.003.
[20] Enni Laine et al., "Platform Ecosystems: Unlocking the Subcontractors' Business Model Opportunities," (25th Annual Conference of the International Group for Lean Construction, Heraklion, Greece, 2017), 177–84, doi:10.24928/2017/0325; Otto Alhava, Enni Laine, and Arto Kiviniemi, "Construction Industry Needs an AirBnb of Its Own!," International Research Conference Shaping Tomorrows Built Environment, September 2017, 566–77.
[21] Duncan W Maxwell and Mathew Aitchison, "Design-Value in the Platform Approach," (25th Annual Conference of the International Group for Lean Construction, Heraklion, Greece, 2017), 349–56, https://iglcstorage.blob.core.windows.net/papers/iglc-de0ccae8-bdc3-4da4-b4c8-a74ef4c150e2.pdf; Duncan W Maxwell, "The Case for Design-Value in Industrialised House Building Platforms: Product to Ecosystem " (The University of Sydney, Forthcoming).

Aims and Objectives

The aim of this paper is to shine a light on a near future design and manufacturing system that helps to improve the overall quality of a new generation of multi-storey housing. Therefore, the research object is a new generation of multi-storey habitat buildings that better responds to current and future human and ecological needs, and make the world more inhabitable.

Research questions:
Our hypothesis is that to do so, an innovative business model and manufacturing approach must be developed, where architectural design knowledge lies at the core of its success. This is addressed through two research questions:

Which design and manufacturing processes can we develop in order to provide a better answer to the specific challenges of multi-storey housing production?

How can architectural design help to inform the creation of an ecosystem for construction?

Methodology

A SPECIFIC ARCHITECTURAL DESIGN APPROACH.

Architectural Design as a discipline is too broad and intricate to assert that there is a single, clear methodology attached to it[22]. We have used an exploratory method, which is useful for situations where there is little existing information[23]. Combined with this research method, is both of the researcher's backgrounds as professional architects, which has assisted the gathering of design related data as well as informing the hypothetical speculation required to envision an open process ecosystem. For this paper's aim, we have distilled the universal themes that are at the core of any multi-storey housing design and building process. When doing this, we are presented with further questions: Can architectural design disciplinary knowledge be applied when developing a full multi-storey habitats design and manufacturing systematization? If so, which specific strategies should be implemented? Is this process an opportunity for innovation in the architectural design disciplinary knowledge?

[22] Linda Groat and David Wang, Architectural Research Methods, 2nd ed., (Hoboken, N.J: John Wiley & Sons, Inc., 2013).
[23] M.J. Polonsky and D. Waller. Designing and managing a Research Project: A Business Student's Guide. (Thousand Oaks, USA: Sage Publications, Inc., 2005)

Findings and discussion

Aspects of product platforms: customization, modularity, commonality, scalability, adaptability, and flexibility.

A. CUSTOMIZATION:
A customized product is designed to meet the specific needs of a particular customer; therefore, customers must be involved in the product realization process. Customized products can be either made to order, tailored to order, assembled to order, or made to stock, each of which has different implications for product platform development and the associated information technologies needed to deliver that product[24]. Until today, most multi-storey habitats are made to order, without the participation of any end-users, instead being commissioned by a real estate developer.

Mass-customization, according to Pine, is “a new way of viewing business competition, one that makes the identification and fulfillment of the wants and needs of individual customers paramount without sacrificing efficiency, effectiveness, and low costs”[25]. Emerging modes of production present new opportunities for mass customization to be realized, presenting a fascinating opportunity in future for a new generation of multi-storey habitats to be realized that involve inhabitants in the design phase. Today, the different modes of occupancy and procurement separates end-users from this initial design phase. This is evident in rental apartments, where the possibility of post-occupancy reverse customization should be key. When a developer thinks about improving its business strategy, can an inhabitant be still addressed as just a consumer?

B. MODULARITY:
Modular products have a one to one or many to one mapping of functional elements to physical structures[26]. Interfaces between components have traditionally been a bottleneck for the proper development of prefabricated solutions, not only between companies, but between different projects within one company. The lack of size standards in the industry is a significant setback when designing for true modularity across construction, from structure and materials, down to furniture and appliances. Again, the diversity of situations might prevent from this from being possible, although it is important that the whole industry starts to move in this direction. Instead, a soft-modularity based on compatibility of interfaces should be pursued. How can we design modular solutions that adapt to each particular case?

C. COMMONALITY:
Commonality can be defined as the reuse and sharing of components, manufacturing processes, architectures, interfaces and infrastructure across the members of a product family[27]. Product platform literature shows a positive bias towards commonality brought about by the manufacturing efficiency benefits of standardization[28]. However, the concepts of divergence and lifecycle offsets provide warnings with regards the challenges associated in realizing these expected benefits[29]. Lifecycle offsets are the temporal differences between the corresponding lifecycle phases of two or more products. Divergence is the idea that commonality declines throughout the product family lifecycle. Which kind of commonality would be more efficient in such long life-span structures as buildings?

[24] Helena Johnsson, “Production Strategies for Pre-Engineering in House-Building: Exploring Product Development Platforms,” Construction Management and Economics 31, no. 9 (September 2013): 941–58. doi:10.1080/01446193.2013.828846.
[25] Pine, J.B. “Mass Customization: The New Frontier in Business Competition”. Boston: Harvard Business School Press, (1993). p.13
[26] Timothy W. Simpson, Jonathan R.A. Maier, Farrokh Mistree, “Product Platform design: method and application”, Res Eng Design 13, (2001): 3.
[27] Timothy W Simpson, Zahed Siddique, and Jianxin Roger Jiao, “Platform-Based Product Family Development,” in Product Platform and Product Family Design, Introduction and Overview, (New York, NY: Springer Science & Business Media, 2006), 1–15.
[28] Lehnerd and Meyer, The Power of Product Platforms.
[29] Ryan Boas, Bruce G. Cameron, Edward F. Crawley, “Divergence and Lifecycle Offsets in Product Families with Commonality”, (October 2012): 176, doi: 10.1002/sys.21223.
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D. SCALABILITY:
According to Simpson et al, “Scalability refers to the capability of a product platform to be ‘scaled’ or ‘stretched’ by varying one or more of its design parameters to satisfy different customer or market requirements. Scalability can be exploited from both a functional and manufacturing standpoint to increase the potential benefits of having a common product platform.”[30] For example, Boeing designs many of his aircrafts by “stretching” them to accommodate more passengers, carry more cargo, or increase flight range[31].

Can a building be scalable? Or just its parts? In multi-storey habitats, scalability presents clear limitations when faced with site, local or national regulations, structural and services efficiency. Opportunities are present in optimizing the design process through component configuration such as walls or windows.

E. FLEXIBILITY:
Flexibility is “the property of a system that is capable of undergoing specified classes of changes with relative ease.”[32] Flexible elements are defined as “elements that can accommodate each product variant’s different requirements through modification at lower additional investment levels, relative to other unique elements that can achieve the same purpose”. [33]

These principles of flexibility apply not only to products, but designs themselves, the result is that changes are not necessarily based on project-to-project variations, but concurrent iterations[34]. Buildings are subject to change from the day they start being used, both by inhabitants and the organizations that take care of them. Habitats, therefore, need to allow change without having to be fundamentally altered. These alterations should be as easy, costless, and waste free, as possible. How can buildings be designed for change?

F. ADAPTABILITY:
Adaptable design aims to develop products that satisfy the various requirements of customers. More broadly it refers to the ability of a design or product to be adapted to new requirements and the reuse of a design or product when requirements change. Adaptable designs can be modified by a manufacturer to generate new designs that improve their products. The product with product adaptability can be changed by a user in a way that is usually reversible and simple, in order to achieve different functions or use. In a building, adaptability is multi-scalar and tackles diverse realms, which as we will see are the object of architectural design processes.

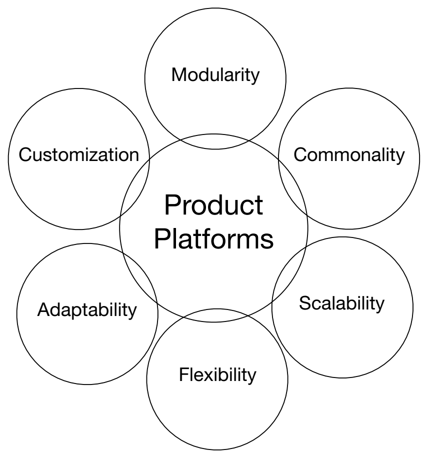

Figure 3. Product Platforms’ six main characteristics.

[30] Timothy W. Simpson, Jonathan R.A. Maier, Farrokh Mistree, “Product Platform design: method and application”, Res Eng Design 13, (2001)
[31] Sabbagh, “Twenty-first Century Jet: The Making and Marketing of the Boeing 777”, (1996).
[32] Moses J et al, “ESD Symposium Committee overview”, in The ESD Internal Symposium, MIT, Cambridge, MA (2002).
[33] Eun Suk Suh, Olivier L. de Weck, David Chang, “Flexible product platforms: framework and case study E (2007): 68-69, doi: 10.1007/s00163-007-0032-z
[34] Hans Johannesson, Joas Landahl, Christoffer Levandowski, Dag Raudberget, “Development of product platforms: Theory and methodology”, in Concurrent Engineering: Research and Application, (2017): 198, doi: 10.1177/1063293X17709866

ARCHITECTURAL DESIGN CHALLENGES OF MULTI-STOREY HABITATS.

The previous section highlights some of the benefits and challenges of a product platform approach for construction. Many challenges that are specific to a multi-storey house design and manufacture arise from an architectural design perspective. Current advances in digitization mean that it is possible to achieve a fully systematized and manufactured approach to human habitats production. However, these structures will fail to succeed, both in the market and in their environmental performance, if the following variables are not brought to the core of their design and manufacture:

1. INHABITABLE SPACE AND TIME:
Complex multi-storey housing is a rather recent way of producing human habitats. However, the need or ability to inhabit the earth is arguably a constituent aspect of our species. Seeking shelter is as old as our species, homo sapiens. That poses some questions that need to be addressed when pursuing a systematized production of human habitats: Can a human habitat be a product? Can an inhabitant be understood as just a customer? Can a product be a home?

2. SITE SPECIFIC:
Each constructed habitat exists on a unique physical location. To render it efficient, not only in terms of performance and endurance, but also of production and transportation, the new system must be able to include all contextual idiosyncrasies, such as its geology, orography, services, local and national codes, neighboring constructions, culture, memory of place, trades and unions, and transport infrastructures. This contextual response must occur in the initial stages of its design and continue through its lifecycle.

3. EXPOSURE TO CLIMATE AND WEATHER:
Each territory, city, and street, has its own macro and micro climatic condition. Hazardous climate change is already affecting our built environment and is a key design driver for the 21st century and beyond. Not only should new habitats adapt to increasingly uncertain and harsh conditions but they should cease being one of the main agents causing it. Resources are increasingly scarce, meaning that processes which make the most of material and energy availability will have the highest chance of success in the market.

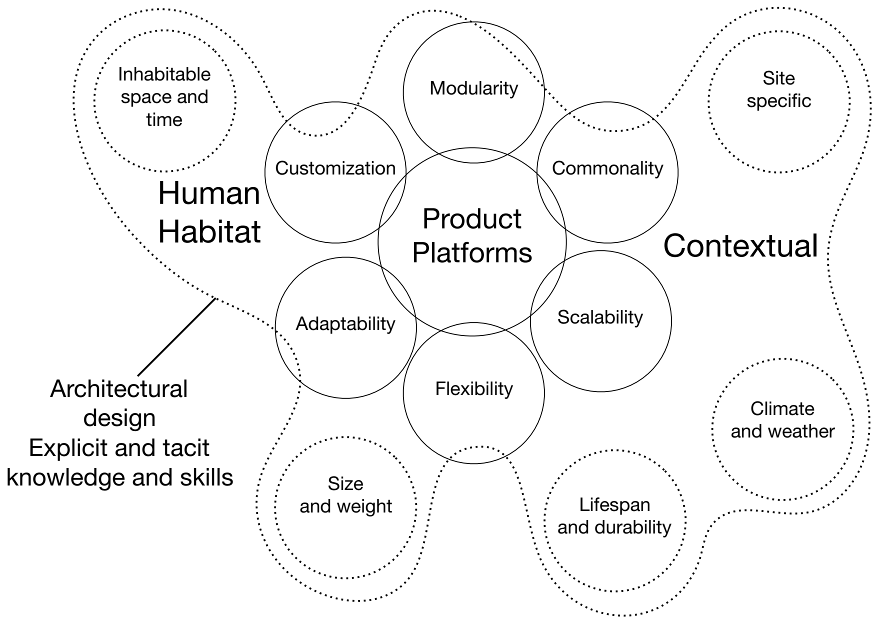

Figure 4. Limits of Product Platforms when applied to multi-storey habitats specificities.

4. LIFESPAN AND DURABILITY:
Built habitats last for generations, surviving the organizations and technologies that built them. Most structures built today become obsolete upon occupation. It is crucial for design strategies to: facilitate low maintenance; provide longer material and functional durability; adapt to uncertainty; allow easy and waste-free repair; and partial or full, slow or fast, change of use.

5. SIZE AND WEIGHT:
Most built habitats are bigger and heavier than ourselves. This means we need auxiliary means to make them. They are bigger and heavier than the means of transportations that humans have been able to develop, thus we must move them in smaller parts. They are also so heavy that they must be attached to the ground. Complex calculations make sure they can resist disasters. These factors together imply that a huge amount of matter and energy is needed not only in their process of materialization but also their operational life. A system that might work in location A might be totally useless in location B.

FROM PRODUCT PLATFORMS TO PROCESS ECOSYSTEMS:

Understanding product platforms alongside the architectural design challenges of multi-storey habitats makes clear that what needs to be systematized is not a product that can be repeated seamlessly and indifferently but rather a process-based approach that embraces difference and diversity. Similarly, the material, information and social heterogeneity that shapes these habitats is of such magnitude that a single platform approach is unable to run the process on its own. A process ecosystem has a far better chance of success. This process ecosystem could work with traditional construction's uncertainty and exposure to externalities, embracing and adapting to context and stakeholders. By deploying a product and process system where knowledge is self-organized or a designed multilayer social network that allows actors to participate in spite of their differing attributes, decision-making principles, and beliefs.

A process ecosystem would build on the principles of emerging platform ecosystems, already discussed, primarily seeking to connect, integrate, and share knowledge[35]. A process ecosystem would extend this concept for construction in order to merge the benefits of product platforms with the idiosyncrasies of multi-storey habitat architectural design.

OPEN SYSTEMS:

Seeking a merged process ecosystem, some researchers have compared and discussed the similarities and differences between biological ecosystems and societal ecosystems. According to Tsujimoto et al., "This exercise sheds light on the management of innovation and technology from different angles. There are many stimulating concepts in biological ecosystem studies, for example, predation, parasitism, symbiosis, decomposition, circulation, trophic level, multiplier effect of chain reactions, and destruction of the whole system". [37]

Open systems in physics and biology informed the basis of General Systems Theory, as defined by Ludwig von Bertalanffy in the 1950s, and which contributed to a significant branch of theoretical knowledge that filtered through to architecture and engineering.[38] Built habitats are not an evolved, but rather a designed, system. However, some biological ecosystem qualities can help to shape process ecosystems. In this paper we address the idea of ecosystems specific to industrial ecosystems. It is important to be aware of the flaws of the industrial ecosystem concept, introduced by Frosch and Gallopoulos in 1989, which still remain unclear today, and therefore be careful with too literal analogies with natural ecosystems.

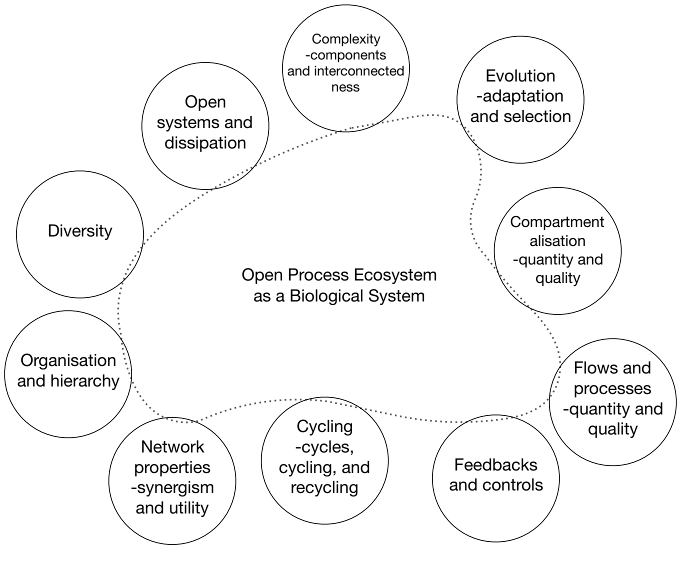

Figure 5. Main properties of biological ecosystems that can be applied to engineered systems.

35 Eloranta and Turunen, "Platforms in Service-Driven Manufacturing: Leveraging Complexity by Connecting, Sharing, and Integrating."
36 Battistella, Colucci, De Toni, Nonino, "Methodology of business ecosystem network analysis: a case study in Telecom Italia Future Centre" (2013): 1194-1210.
37 Masaharu Tsujimoto, Yuya Kajikawa, Junichi Tomita, Yoichi Matsumoto, "A review of the ecosystem concept – Towards coherent ecosystem design" (2017): 8, doi: 10.1016/j.techfore.2017.06.032
38 Ludwig von Bertalanffy, "The Theory of Open Systems in Physics and Biology," Science 111 (January 13, 1950): 23–29.

OPEN PROCESS ECOSYSTEMS:

An Open Process Ecosystem for construction must implement a design and manufacturing methodology that is based on customization, modularity, commonality, scalability, flexibility and adaptability, but that also includes the specific constraints of multi-storey habitats in its architecture. In terms of organization, a dynamic and self-adapting ecosystem based on collaboration, interoperability and context, which offers an environment for enterprises and partners to rapidly align their business and production needs. This is organized around:

a. A strong and diverse team of in-house architects.
b. Fostering innovation through collaboration with University research laboratories and other stakeholders.
c. Joint ventures to develop innovative products and solutions, with both external designers and manufacturers.
d. Greater involvement of community and inhabitants in all lifecycle stages of multi-storey habitats.

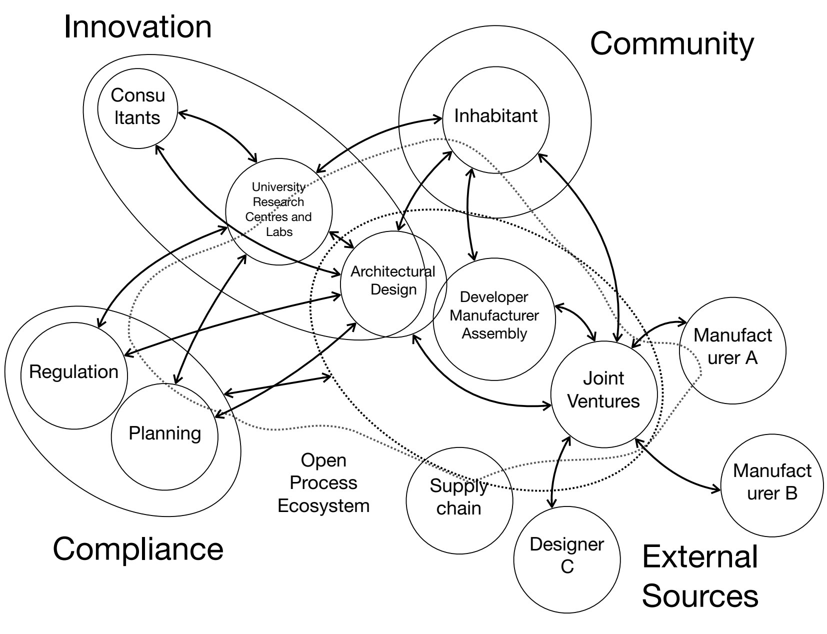

Figure 6. An Open Process Ecosystem for a multi-storey habitats design and manufacturing.

Conclusions

An Open Process Ecosystem is a methodological framework for a potentially efficient and ecologically-focused multi-storey habitats design and manufacturing industry. With our planet's current level of urbanization, even if construction could agree to standardize sizes and modules, future habitats will still need to adapt to each site of construction and user group, in order to be fully efficient, functional and inhabitable. Architectural design is the discipline that can develop the knowledge and tools to make this possible.

This systematization will also bring innovation to architectural design as a discipline. Further research is required to clarify these contributions to the field of architecture, while refining the Open Process Ecosystem concept for business, this will be achieved by applying these findings to a specific case study.

ACKNOWLEDGEMENT

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