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Buildings Definition as Product-Service Systems

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Résumé :

Le Système Produit-Service est une des nombreuses solutions de conception menant au développement durable. Une des difficultés du SPS porte sur l'allocation des fonctions du système entre la partie produit et la partie service. En Architecture-Ingénierie-Construction, l'allocation des fonctions au bâtiment ou au service proposé est également un challenge. La Maîtrise d'Ouvrage se doit de traiter cette question au moment de la définition des exigences, en amont de la conception. Cet article propose de l'aborder au travers d'une adaptation et une application des concepts de « Function Behaviour Structure » de Gero à la définition des exigences d'un bâtiment que nous considérons comme un SPS. La décomposition FBS proposée est illustrée sur un exemple de cuisine pour une maison de retraite.

Abstract:

Product-Service System is one way toward sustainable system development. One issue of PSS concerns the function allocation between the product part and the service part. In Architecture-Engineering-Construction, function assignment to either the building or the service offered is also a strong issue. The contracting owner (i.e. paying client) has to deal with this issue during the requirements definition. This paper proposes to tackle it through an adaptation and application of Gero's Function-Behaviour-Structure design concept to the requirements definition of building systems considered as PSS. The proposed FBS decomposition is illustrated on the example of a kitchen in a retirement home.

Keywords: **architectural programming, conceptual design, building, FBS, PSS**

Mots clefs: **programmation architecturale, preconception, bâtiment, FBS, PSS**

1 Introduction

Sustainable development aims at reducing the global impact of a system on its environment. One way to tackle this question is Product-Service Systems (PSS): shift from product ownership toward utilisation and functionality [13]. Functions are thereafter associated to a service part of the PSS instead of the usual product through, for example, dematerialisation or product substitution [8]. This solution could lead to sustainable solution if the rebound effects [10] is anticipated and controlled. It is a necessary condition but not sufficient. One of the issues in PSS development is the function allocation between the product part and the service part [15] during the conceptual design phase.

In Architecture-Engineering-Construction (AEC), the architectural programming phase deals with the definition of the future building. It corresponds to the conceptual design phase of a manufacturing product. During this phase, the service to provide to users is also defined and it heavily conditions the definition of the future building. Functions of the building system are therefore split between a product part represented by the building and a service part represented by the human "operators" activity of servicing the users (e.g. education in a public school). Here comes the issue of how to attribute functions between the building and the human activity? Too often a building does not meet elementary requirements regarding the service (i.e.

human activity) to provide. As a matter of fact, the service is only outlined at the beginning of the conceptual phase and very lately detailed, sometimes even after the building was delivered.

In this paper, buildings are considered as PSS due to their dual composition of static building and dynamic human activity. The contribution focuses on the adaptation and interpretation of the Function-Behaviour-Structure (FBS) concept developed by Gero [4] to the conceptual definition of a building in order to facilitate and/or structure the function allocation between its two major components. This contribution is developed based on a literature review on FBS and a structural decomposition of buildings as a PSS.

Section 2 of this paper briefly introduces the building as a PSS. Section 3 focuses on the FBS concepts starting from Gero's root definition toward its adaptation to buildings as PSS. Section 4 illustrates the FBS adaptation to a retirement home regarding a single function: feed the elderly. Section 5 discusses and concludes the reflections proposed in the paper regarding PSS, FBS and buildings.

2 Product-Service System

2.1 Definition

PSS is usually defined as a business model in literature. In this paper, PSS is considered as a mindset regarding Goedkoop et al.'s definition: "A Product Service system is a marketable set of products and services, jointly capable of fulfilling a client's need." [6]. There is a first notion of integration between a product part and a service part and a second notion of alignment between these two parts. Moritz differentiates a product and a service regarding seven qualities [14]: produced/performed, material/immaterial, tangible/intangible, can/cannot be stored, usually without client or with interaction with client, consumed after/during production, and regarding the origins of defaults either from manufacturing or behaviour. Even if it could be discussed, this characterization brings more details to understand both concepts. This understanding served as a basis to analyse and to decompose a building system.

2.2 Buildings as Product-Service System

This paper is limited to buildings that hosts a service provided to a public by a set of operators hired either by the State or a private company (e.g. school, library, hospital). Both the public and the operators are considered as users of the building. The concept of business model (i.e. way of selling the system, its marketable property) is removed from considerations of this paper to focus on the structural composition of building systems.

A building system is defined as the global answer to a contracting owner issue regarding a current unsatisfying state. In the case of a school, the contracting owner does not need only a building to solve an overcrowded schools issue. In this case, he will have students in a brand new building but no one to take care of them. The contracting owner needs a complex system composed of this building, people who can provide education, equipment to support the activities related to education, energy to make these equipment work, and from time to time an IT system to manage, inter alia, information about teachers and students. This global vision fits with the aim of architectural programming about buildings definition. Education is therefore a service and all the other components are resources that are required in order to perform it. These resources have to be dimensioned regarding this service. They materialize the "how to" of the service. That is why they are considered as products.

A building system has to answer to the education requirements but not only. It has to fulfil other functional and non-functional requirements. For example, it has to provide shelter to its users. This function is not met by a service but by a part of the building: the roof. Another requirement to fulfil concerns the safety of children in secondary schools. This safety could be met by different solution principles. First one would consist in using mainly the building and its architecture like in Bentham's Panopticon [1]. Second possibility would be to use specific equipment like closed-circuit television as describe by Orwell's 1984 [16]. Third option would be a purely "service" solution principle by asking teachers to make daily rounds in the school following a schedule. Last solution principle would be to combine parts of the service activities with parts of the products/resources. The building would be designed to improve passive oversight by the teachers from their office favouring the use of see-through materials for the walls. Thereafter, the allocation of the functions to the components of a building system becomes a challenge.

As a result, the system defines the whole complex solution to the contracting owner specific issues. This system is composed by a set of Products and a Service. Products include the building to be designed by the architect and human and material resources to be dimensioned by the contracting owner. The Service refers to the direct and indirect interactions (i.e. activities and processes) between the operators who perform the Service and the users who benefit from the Service.

The Function allocation is not a design issue but a requirements definition issue. It corresponds to programmatic concepts [17] in AEC. Thereafter, it is the contracting owner's responsibility. The architect just has to deal with the design and construction of the building part. The contracting owner should specify the functional organization of his building system in the brief. The functional organization includes the definition of the human organization, the service activities and space planning of the future building. Actually, the contracting owner limits himself to outline the service and focuses more on technically defining the building so as current briefing practices tend to be solution-focused or solution rationales [11]. As a result, architects are limited in their design and the resulting building does not fit with the real requirements of the contracting owner. The contracting owner should define the functions to achieve by the building system but also to determine whether it should be the service or the building that has to do it. At least, he has to define as precisely as possible the service that will be provided to better define the building that will host it.

3 Function-Behaviour-Structure

3.1 Gero's FBS

In order to support the contracting owner in this function allocation, this research work proposes to structure it around the three fundamental concepts defined by Gero: Function-Behaviour-Structure [5]. Function refers to what the system is for, its purpose. Behaviour refers to what the system does, its attributes derived or expected. Structure refers to what the system is, i.e. its composition. Their dynamic relations (figure 1) are first described in a framework [4] then situated in [5]. This framework was developed regarding the design process. In this paper, the structure is adapted for the requirements definition and function allocation based on programmatic concepts (i.e. high level solution principles).

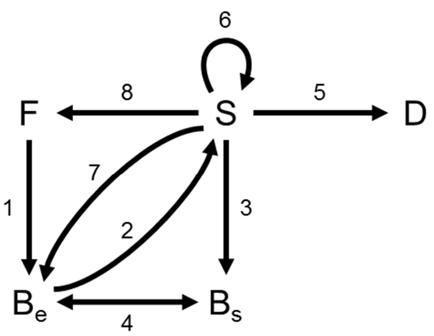

FIG. 1 – Gero's FBS framework, based on [5].

3.2 Building System FBS

Programmatic concepts refer to general or abstract solution principles to the contracting owner's architectural problem [17]. These concepts are mainly functional and organizational ideas that outline and guide the architect in his architectural design. Peña defines 23 kinds of programmatic concepts regarding 4 dimensions: Function, Form, Economy, and Time [17]. He makes the distinction between the programmatic concept, which defines the Functions and outlines the associated Behaviours and Structure, and the design concept, which refers to the drawing of the Structure, its materialization, by the architects.

In this research, Function is associated to service function to be achieved by the building system as defined in Mechanical Engineering. The building is seen as a component of this complex system. One of the main service functions assigned to the building part is "to host the Service delivered". This Service corresponds to education in a school.

Behaviour states the dynamic interactions between components of the building system (i.e. the Structure). It contains the Service to provide using the Structure elements and its description in terms of “what” and “how”. Its definition is split in two. The first part concerns Behaviour of the Products ($B_{Products}$) as in Gero’s original definition whereas the second refers to Behaviour of the Service ($B_{Service}$). Service is defined by a combination of processes, activities, people skills and supported by materials [12] that this research completed with information flows and expected performances. Processes, activities, people skills, information and performances are not physical entities. Therefore, they are considered as Behaviours associated to either the Service or the Products (Structure).

Structure provides the structural (physical) decomposition of the building system. From this paper point of view, a building system is composed by the building that hosts the whole, equipment or materials required to performed activities, energy needed to supply equipment, people who perform the activities using equipment, and the IT system that manage flow of information between activities. All of them are considered as Products in a broad sense.

As a result, the architectural programming aims at the definition of the building system Functions and their assignment to Services (i.e. Behaviours), Products (i.e. Structure) or a combination of both. This issue and their integration are dealt by deciding on programmatic concepts. Decisions are directed by Quality, Economy and Time: Quality regarding the performance and objectives pursued by the contracting owner, Economy considering the global cost of the solution principles, and Time depending on the delay required to define, design, or build solution elements. At the programming step, most of them rely on assertions or assumptions about the current and future context, i.e. subjected to changes over the time.

4 Retirement Home Kitchen Illustration

This section illustrates the FBS and PSS principle applied to the building system: from a purely product solution principle toward a purely service one. The chosen example is a retirement home. For a single Function to be achieved by the building system, “Feed the residents”, five different solution principles or programmatic concepts are exposed. Each one of them is supported by a set of assertions, assumptions or objectives about the present and future context that would lead the decision making.

4.1 Self-Catering

In this first scenario, the management of the facility choose to favour or at least ensure the autonomy of its residents. The programmatic concept consists in foreseeing individual kitchens more or less equipped attached to each small apartment. Therefore, three kinds of solution principles can be considered.

4.1.1 Example 1: Easy Self-Catering

In this example, the elderly are fully autonomous for the cooking but with low level competencies or abilities. They can still drive by themselves and do their own groceries. They want fresh food but do not want to spend too much time in cooking ($B_{Service}$). A solution principle would be to provide them with a small kitchen with storage for all kinds of food and a multifunctional culinary food processor ($B_{Products}$) as single cooking equipment (Structure). They can choose what they want to eat and cook it themselves without assistance. As a result, the kitchen does not need to be large and functional. It can be opened to the living room to save space. Space can thereafter be devoted to other usage in acquaintance with the elderly preferences. This is a purely product solution principle.

4.1.2 Example 2: Semi-Dependent Self-Catering

The elderly do not want to cook but to eat whenever and whatever they want. They can still drive by themselves and do their own groceries. They prefer eating ready-prepared or ready-cooked dish ($B_{Products}$). As a result, the kitchen required to be minimal with mainly frozen and cold storage and an oven or microwave (Structure). As a result, the kitchen is a little bigger than in the first example. It is considered as a mainly product and service solution as the meal cooking ($B_{Service}$) is subcontracted to someone else. All that is remaining is warming up the meal ($B_{Products}$).

4.1.3 Example 3: Independent Self-Catering

Here you have independent healthy elderly. They prefer home cooking and continue to do it themselves ($B_{Products}$). They are provided with a standard functional kitchen (Structure). The cooking is done internally, they perform the service themselves ($B_{Service}$).

4.2 Collective Catering

In this second scenario, the management of the facility expects that:

- Elderly needs day to day assistance, or
- That a kitchen is too dangerous to deal with regarding their state, or
- Simply that it is too expansive to provide elderly with an individual kitchen.

The first two assumptions are related to Behaviours of Products (i.e. the elderly and the kitchen) whereas the third one refers to a financial constraint (Function). Therefore, the individual kitchens are replaced by a collective centralized catering controlled by the management of the facility.

4.2.1 Example 4: Refectory

In this example, the collective catering ($B_{Service}$) is managed in a refectory. All the elderly are gathered during the meals to foster social interaction between residents. It supposes that all of them are able to move or can be assisted to go from their room to join the refectory. A professional kitchen supports this with a team of professional cookers and waiters as in a restaurant. As a result, two large spaces and a smaller one have to be plan in the building (Structure). The first one would be for the welcoming of the residents in the refectory. The second would be the kitchen full of “industrial” equipment. The small space is the changing room for the personal. Another possibility could be to deliver the meal room by room. It spares the refectory space but required standard or limited choices of meal for the residents ($B_{Service}$).

4.2.2 Example 5: Individual Room Catering

In this last case, elderly are considered too weak to be able to join a refectory ($B_{Products}$) and the management do not wish to provide additional personal to deal with it ($B_{Service}$), or it is too expansive in terms of space and money (Function). Instead of having the catering done inside the retirement home, it is completely outsourced to an external company that delivers the meal directly to the room without required warming ($B_{Service}$). This solution principle brings new requirements or has an impact on circulations and security inside the building ($B_{Product}$). It is a purely service solution principle. Specific organization is required but it spares a lot of spaces and equipment.

4.2.3 Synthesis

In this short example, a single Function of one building system was declined into five different solution principles. Each one of them defined specific Behaviours of either its Service part or its Product part. The Structure associated to each scenario was impacted by the decision made. Each Product (i.e. resource) evolves in terms of quality and quantity whereas the Service changes from being performed internally to externally. The Structure decomposition of the presented solution principles is summarized in Table 1.

Table 1. Synthesis of the 5 solution principles (or programmatic concepts).

	Easy Home Cooking	**Ready-Cooked**	**Standard**	**Professional**	**Lunch Service**
Service	0	Internal/External	Internal	Internal	External
People	Low level cooker	Zero cooking skill person Industrial cooker	Medium level cooker	Expert cooker	Professional cooker
Equipment	Thermomix Minimal kitchen	Minimal kitchen	Functional kitchen	Industrial kitchen	0
Building	Small kitchen	Small kitchen	Standard kitchen	Big kitchen	0

5 Conclusion

The objective of this research paper is to propose a way to facilitate and structure the function allocation in the definition of a building system. The building system is defined as a complex system (i.e. PSS) composed by two highly dependent sub-systems (i.e. a product part and a service part). The proposed approach is based on the FBS design concepts developed by Gero, adapted and applied to the requirements definition phase of building systems. The design concept of Behaviour is divided in two requirements definition concepts: Behaviour of the Products and Behaviour of the Service. $B_{Products}$ corresponds to Gero's definition of Behaviour regarding manufacturing systems whereas $B_{Service}$ refers to human activities required to perform a Service. The definition of the Service and the context of the project fit better to the contracting owner knowledge and competencies as illustrated in the retirement home example. Thereby, the function allocation is performed based on objectives, assertions and assumptions defined upstream by the contracting owner. The decision to assign a function to the building or resources (i.e. Products) or to the Service performed is therefore done through the definition of the expected Behaviours.

The proposed approach still requires an assessment and validation on a practical case study with a contracting owner. A first phase of interviews with contracting owners and architects has begun in order to assess the relevancy of the approach and its potential application. For the time being, the proposition corresponds to the essence of architectural programming. The function allocation between $B_{Service}$ and $B_{Products}$ fits to a larger definition of the programmatic concepts. Its practical application remains an open question for interviewed professionals. The next step in the research project will be to apply it on a real on-going project.

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