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# A GENERIC SYNTHETIC FRAMEWORK FOR CONCEPTUAL SERVICE DESIGN

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*Keywords: service, product service system, conceptual design, life cycle design, dimensional analysis, topology*

## 1. Introduction

### 1.1 Scope

The limited availability of natural resources associated with the constraints in energy supplies, and the restricted ability of the earth to accept industrially generated waste led to an obvious discrepancy between energy production needs and the sustainability of the actual economical system. This untenable evolution directly involves the design and production sciences by developing and manufacturing an increasing number of artefacts disposed of at the end of the life cycle. Unless we develop alternative technologies, create economical and environmental limitations and question the concepts of economical growth, the future of our planet is at risk.
This analysis has led to the creation of the Post Mass Production Paradigm (PMPP) developed by Tomiyama [Tomiyama, 2001]. The PMPP aims at qualitative satisfaction rather than quantitative sufficiency by decoupling economic growth from material and energy consumption. Unfortunately, this paradigm may not in practice guarantee less environmental impact. Without questioning the growth paradigm, the PMPP paradigm and the Product System Service (PSS) framework [Mont, 2002] [McAloone and Andreasen, 2004] will probably lead to smaller environmental performances than expected.
Nevertheless, shifting to another paradigm is probably out of the scope of this article. Thereby this article, only discusses the conceptual design process by presenting the basic features of a Conceptual Service System intended to revisit the scope of conceptual design by looking at service. Thus, this paper’s framework represents an extension of the existing generic conceptual framework developed by the main author of this article in his PhD thesis [Coatanéa, 2005].

### 1.2 Motivation and methodology

The fundamental goal of our research is to support the foundry industry in Finland by providing them new tools and approaches. Thus, this paper’s framework intends to model service, and compare and evaluate a product from a service perspective at the early stage. Furthermore, our approach is closely related to the area of life cycle engineering and Design for X. Yet, this paper has a wider scope by trying to make a synthesis of a new approach. First, the idea is to shift from a traditional product centred approach to service which is based on the central hypothesis that service contents will become crucial for the future of manufacturing industry [Tomiyama, 2001]. Second, this initial hypothesis, if associated with the fact that most of the characteristics of a future product are set during the design phase and more specifically during the conceptual design process, demonstrates that the conceptual design of service is probably a fruitful niche of research. This means in practice that the design activity cannot anymore be limited to the creation of new artefacts. Thereby the current practices, methodologies, and tools to design artefacts should be revisited. Furthermore, products should comprise more added values coming from a deeper knowledge about product life cycle and service contents, in order to move from a materialistic vision to qualitative satisfaction. To this end, we need engineering methods to look at services rather than just functions. We claim that the generic framework developed in the PhD thesis of Eric Coatanéa [Coatanéa, 2005] can support such type of paradigm evolution.

The field is still new and our intention in this paper is to show that this framework includes the characteristics to investigate the enlarged scope of the conceptual design activity proposed in this paper.

This paper first outlines the current state of affairs based on two complementary approaches regarding services, Service Engineering [Yoshikawa, 2001] and the Product Service System (PSS) [Mont, 2002] [McAloone and Andreasen, 2004] respectively.

Then, this article demonstrates than strong similarity exists between the central concept of service and the concept of function developed in the doctoral thesis of Coatanéa [Coatanéa, 2005]. The fundamental consequences of this analysis such as a transposition of the concept of service into the framework developed by Coatanéa are discussed.

We then present the main characteristics of a methodology dedicated to service design based on the framework developed by Coatanéa. The goal is to describe the main steps of the service design method, the semantic description of the service problem, the approach used to flow from semantic description to concepts solutions for service engineering, the comparison and evaluation aspects of concepts of solutions for service engineering are introduced via a generic metric framework intended to ensure repeatability and measurability.

The last part of the paper presents the fundamental metric system intended to measure the service characteristics defined in the initial part. The fundamental conditions required aimed at mathematical machinery aimed at transforming the initial topological framework into to transform a service design problem, which is modelled by several metrics into a problem described by a unique metric, is presented.

The paper concludes by discussing the main proposal of this article and the next formalization steps and implementations required to evaluate the methodology.

## 2. State of affairs surrounding service

The goal of the present section is to present two complementary approaches dealing with the concept of service; both approaches consider a global change in the paradigm of engineering design. The aim is not anymore to focus on the design and development of simple artefact but to extend the scope of the activity by integrating the entire Product Service System (PSS). The PSS concept has the potential to bring about such changes in production and consumption patterns that might accelerate the shift towards more sustainable practices and societies by considering issues as utility, sustainability and societal values. The first part of this section is defining the concept of service. The second part determines the main characteristics of a Product Service System.

### 2.1 Service engineering

Service engineering is based on the fundamental argument that intensifying the service content is a crucial aspect for the manufacturing industry. This initial hypothesis can affect three aspects of the manufacturing industry.

First, service can be used as a way to diminish the environmental impact. This argument assumes that services as opposed to physical products can result in less environmental impact. This hypothesis is not always guaranteed for example washing machine-sharing can result in increasing use of electricity and detergent. This is known as the rebound effect. In order to avoid this bias, the eco-efficiency of service needs to be taken into account. Eco-efficiency can be defined as a way to bring together the two dimensions of economy and ecology to relate product or service value to environmental influence [WBCSD, 2000]. Eco-efficiency may be represented by the following ratio:

$$\text{Eco-efficiency} = \frac{\text{Product or service value}}{\text{Environmental influence}}$$

Second, service can provide more added values by extending services to every stage of life cycle. For example, by incorporating maintenance services into product sales, car companies can expect more added values in addition to product sales.

Third, selling use and functions is another way to increase service contents. This strategy tends to replace sales of physical products with rental and lease services.

The service engineering framework is based on fundamental definitions and concepts. First, the definition of a service; the definition of service retained in this article is the one given by Tomiyama [Tomiyama, 2001]. Service has some fundamental characteristics which are listed below:

- Service is an activity. An activity is a series of procedures provided by a service provider to a service receiver.
- Service cannot be stored and it disappears instantly.

In addition, services have many similarities with the concept of information. To be delivered a service requires *a channel*. This channel transfers *the content* of the service from *the provider* to *the receiver* of this service.

In addition, some extra characteristics can be added to this initial pattern describing services. It is important to note that services need pre-requirements, which are first the exchange of *information* between the future receiver and the future provider in order to identify *the service goal*, the service channel, the service content and the prize of the service. In order to measure the satisfaction of the receiver, both the fact that the service has been realized and the *quality of the service* had to be quantified. The difference between *the realized service* and the service goal creates the *service value*. The service itself is performed in a certain environment which is the *service environment*.

The service provider provides the service to the receiver with service contents through a service channel. The activity of providing the service is *the service body*. The services themselves are classified in three categories:

1. Message type service. In this type of service, the content of the service is information. For example, a wireless communication is a message type service. The information itself can be dematerialized or sent via a physical support, for example via paper.
2. Massage type service. This type of service type is similar to the message type service except that the service body has physical effects. This can be transporting a receiver in order to make him moving from one point to another by using a service channel which can be for example a bicycle or a plane. The move of the receiver is the service content.
3. Proxy type service. This type of service is characterized by automation of receiving and sending. The proxy service is an intermediate between a provider and a receiver. A travel agency can be for example a proxy service between a traveller and a hotel.

In addition to this initial list of service types, Tomiyama and his colleagues [Tomiyama et al., 2004] define two extra types of services called *convenience/enabling type service* and *service associated with product Life Cycle* respectively. It is argued in this article that the convenience/enabling type service cannot be considered as specific types of services. The characteristics of taking place "anywhere" and "anytime" are not sufficient to characterize a specific service type. The proposal is to integrate in the three initial types of service these two specific characteristics. By contrast, to this comment the service associated with product life cycle can really be considered as a service because the *service targets* are not the providers or the receivers but the artefacts used as service channel.

## 2.2 Product Service System

Goedkoop [Goedkoop et al., 1999] has defined the term Product Service system (PSS) as "a marketable set of products and services capable of jointly fulfilling a user's need. The product/service ratio in this set can vary, either in terms of function fulfilment or economic value". It is important for studying and designing the PSSs elements to provide a common term of reference. PSSs consist of a combination of eco-designed products, reinforced by designed services at different stages of a product's life cycle, and comprising different concepts of the product use (both use and result oriented), closely involving actors in the chain and outside. A PSS is articulated around a series of key concepts, which closely related to:

- The *product service period* which is the part of the product life cycle when the product serves the user and provides utility.
- The *product service system strategy* is the strategy of offering service together with or related to product sales.
- The *Service Offer* is the service potentially delivered by the provider to the receiver.

### 2.3 Synthesis of the conceptual framework related to service

Based on this initial presentation, it can be noted that products substituted by services are largely an ideal category without many practical or consistent examples, because any service, even nonmaterial as such, requires material or energy inputs. Using the interaction graph belonging to the APTE® method [APTE®] (see figure below), it is possible to represent some elements belonging to the concept of service. In the following section, Figure 1 will be compared with another interaction graph representing a concept of function [Coatanéa, 2005].

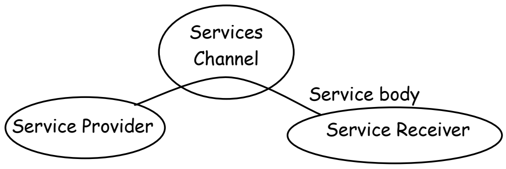


**Figure 1. Interaction graph of service elements**

In addition, we have noticed when analysing the service categorization provided by Tomiyama et al. [Tomiyama et al, 2004] that the service contents were always divided in three fundamental types:

- Service contents in the form of a physical object/or an energy transferred to a physical object,
- Service contents in the form of a signal (information),
- Service contents in the form of money (materialized or dematerialized),

We claim here that service contents are formed of three domains (i.e. physical, informational and economical). This is also the case for engineering design.

Furthermore, when comparing the interactions of service receivers/providers and customers/designers, from a service design and engineering design viewpoint respectively; they both exhibit a similar methodological pattern. Indeed, first they both try to define the aim of the activity performed by the service or the future product. To proceed this way they require to exchange information and to take into account the environment of the project. The service categories defined by Tomiyama can be compared with families of products or basic organs [Hubka, Andreasen and Eder, 1988] when analysed from the systematic approach of design engineering popularized by Pahl and Beitz [Pahl and Beitz, 1984].

Consequently, from this initial analysis, it appears that similarities between the concepts and the approaches of service engineering and design engineering might probably be underlined. This seems to be natural as long as service engineering is seen as an extension of the scope of the design engineering. Nevertheless, this approach can be useful if the goal is to define a service design methodology.

The following section is comparing the present framework with the framework developed by Coatanéa [Coatanéa, 2005].

## 3. Comparison of the concepts of service with an existing framework

The doctorate thesis of the main author has permitted to develop a conceptual framework dedicated to the life cycle design. This model is constructed out of several elements:

- A generic definition of the concept of function,

- The definition of a generic categorization of the elements belonging to the conceptual engineering design methodology,
- A fundamental system of quantities,
- A series of fundamental conditions enabling the transformation of the initial engineering design problem into an engineering design problem described via a unique metric,
- An algorithm which allow this transformation,

The limited format of this article obliges us to restrict the scope of the presentation to the three first elements and to the comparison of these concepts with the elements of the service engineering.

### 3.1 Function as an interface between two situations

During the conceptual design phase, it is important to provide appropriate analytical concepts to designers in order to extend the scope of the research of concept of solutions. An appropriate concept of function can increase the chance of creating innovative solutions. Consequently, a function should remain an abstract concept not dedicated to a specific technical solution. Then, the formulation of function should shift the design question from "What is D's function?" to "How does it function?" As a result, the concept of function is not anymore something intrinsic to a machine.

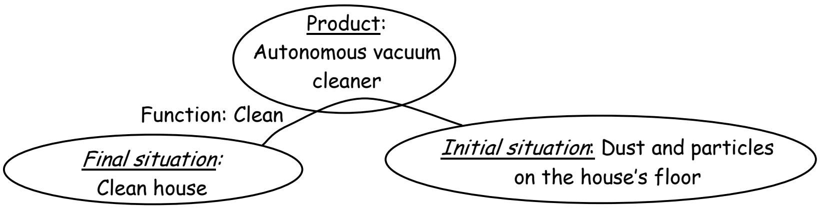


**Figure 2. Interaction graph of a vacuum cleaner**

This fundamental hypothesis has supported the definition of a concept of function retained in the main author doctoral thesis [Coatanéa, 2005]. A function is defined as the interface between an initial situation and a final situation. It is possible to represent the overall function of a vacuum cleaner according to the figure 2.

A situation exhibits several fundamental characteristics:

- the nature of a physical substance,
- the localization in space at a given time,
- the domain of the analysis,
- the nature of the action applied on the physical substance,

According to the definition retained in the work, a situation is defined as the state(s) of the elements in the environment within a volume of time and space. A state is described by material entities, attributes related to these entities, and relations between them.

These characteristics are summarized according to the classification of the Table 1.

**Table 1. The situation structure in this thesis**

| | Family | first class | secondary class | third class |
|---|---|---|---|---|
| *Situation* | | | | |
| | *States* | | | |
| | | *Material entities (substance)* | | |
| | | | *Laws* | |
| | | | | *Attributes* |
| Within a | | | | |
| *Volume of time* | | | | |
| *Volume of space* | | | | |

### 3.2 Categorizations in the conceptual engineering framework

The classifications of the conceptual engineering elements developed in the PhD Thesis of Eric Coatanéa are based on a series of generic concepts. These concepts are associated with graphical steps, which correspond to the designer's tasks. The following figures 3 and 4 summarize the concepts, the graphical representations and the design tasks.

### 3.3 Discussion and similarities between the two models

The comparison of the Figures 1 and 2 exhibits evident similitude between Service body and function. Service body can be considered as an extension of a function. Similarly, Service channel is as an extension of the concept of product. On the other hand, the service content can be classified according to the three fundamental domains defined in the conceptual framework named physical, informational and economical domains. The conceptual framework elements, domains and situations are in our viewpoint suitable elements in order to support clarifications about the aim of the receiver's activity, the service goal and the service targets. They can help defining the environment when designing a service. Nevertheless, this initial analysis is still very much conceptual and further work may lead to a better formalization.

In addition, the categorization of variables, the definition of complex mechanisms and basic mechanisms associated with the definition of different levels of graphical analysis constitutes an interesting basis to support the quantitative evaluation of services. Indeed, we assume that the variables can be used in the modelling process of service because they exist in the three domains shared by service engineering and design engineering. In addition, the basic mechanisms and the complex mechanisms can support also analysis in these three domains.

Nevertheless, another basis is required in order to quantitatively evaluating service. This basis is a fundamental system of quantities. This system of quantities is presented in the following section.

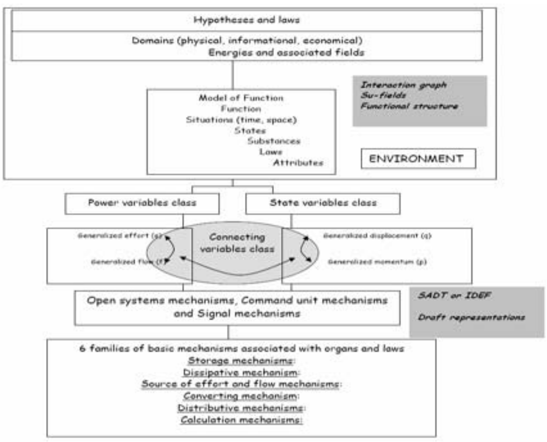


**Figure 3. Categorization of design elements**

| Graphical steps | Designer tasks |
|---|---|
| Interaction graph | Clarifying the goal of the design activity |
| Su-field analysis | Problem solving |
| Functional structure modelling<br>SADT or IDEF family graphs<br>Draft representation | Synthesis of solution |

**Figure 4. Graphical steps and tasks**

### 3.4 An enhanced system of fundamental quantities for service design

It has been presented several times that the design process is dealing with three domains. Consequently, metrics should be associated with the quantities of the domains in order to ensure that the attributes used to describe the various models are countable and measurable. This is traditionally done for a set of physical attributes using the international system of quantity (SI system) composed of 7 base quantities -length, time, mass, temperature, current, number of elementary particles, and luminous intensity-. Nevertheless, this system does not have any fundamental quantity related to the economical and informational domains, which constitute an important sector of the design activity. We argue that design activity requires two extra fundamental quantities in order to ensure that *a* *fundamental countable system of entourage* can be created. These two quantities are the quantity of information symbolized by *Sh* and the economical quantity symbolized by *C*. The units of these two quantities are respectively the Shannon (Sh) and any currency types for example € or $. We assume that these metrics can measure factors of the service quality such as capacity, efficiency, cost, time, timeless, frequency, punctuality, flexibility, customizability, security, safety, comfort, and so one [Coatanéa, 2005].

### 3.5 Example of conceptual service design analysed with this framework

The framework presented above has been presented to partners belonging to the Finnish foundry industry in order to design and evaluate new types of services, which can be provided by founders to their clients. This is a strategic element for the future of the foundry business in Finland. In our framework, the *service provider* is the foundry industry or an intermediate, the *service receiver* is the client. The *service period* is related to the design, manufacturing and assembly phases of a product. The *service strategy* consists of improving the position of the foundry industry in the supply chain. Different types of *service bodies* or *service offers* are evaluated according to the domains where they are active (*informational, physical or economical*). *Massage type of service* (*physical domain*) are tested when the foundries extend their offer by providing machining of parts and assembly of modules for their clients. *Message type of service* (*informational domain*) are evaluated by the founders, the idea consists of extending the design content of the founders and more generally creating a consulting activity in addition to the traditional foundry business. Another type of service called *proxy service type* is evaluated by evaluating the role of intermediate design offices located between the client and the founder. We are now trying to analyze different aspects of the *service channels* (type of communication format, development of a common design language, etc…) in order to make them functional between founders and clients.

## 4. Conclusion

This paper proposes an approach aimed at formalizing and quantifying a service design methodology. We assume that this formalization is important to achieve our goal of helping the Finnish founders to shift there concern from production of casting parts to production of a casting service. First, it is shown that the concepts of service channel and service content are extensions of the concepts of product and function respectively. This initial work shows that the framework developed to capture conceptual life cycle design can probably capture also service and can potentially cover a wide variety of services. Second, the paper presents a group of fundamental metrics originally dedicated to cover conceptual life cycle design and shows that they can also cover the quantitative requirements related services design elements. At this stage, the methodology is still very much conceptual. However, future work will improve the classification and categorization of existing services and will allow developing a computer-based implementation covering simultaneously traditional conceptual life cycle design and service design.


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